SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Productive Research—Thomas

Sewage Effluents in Crop Irrigation—Henry, et al

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FEBRUARY, 1954—VOL. 26, No. 2

Make Plans to Attend

27TH ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

IN CONJUNCTION WITH

OHIO SEWAGE AND INDUSTRIAL WASTES TREATMENT CONFERENCE

NETHERLAND PLAZA HOTEL
CINCINNATI, OHIO

October 11-14, 1954

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS
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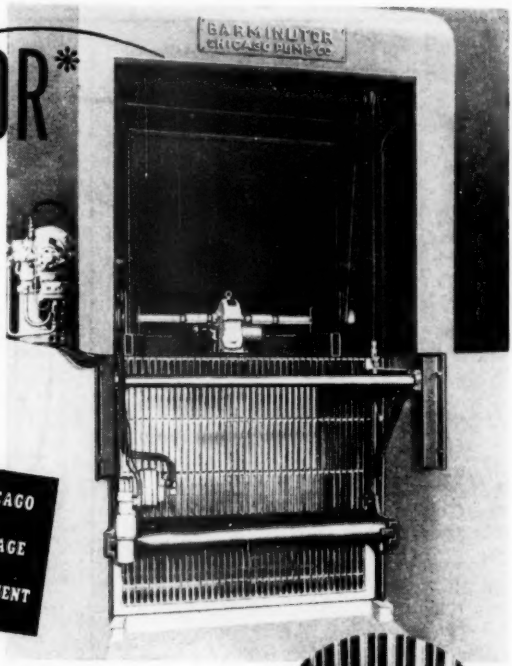
BARMINUTOR*

A New Comminution Development

CHICAGO SEWAGE EQUIPMENT



Barminutor installed in 5' channel.

The Barminutor Model "A" exclusively provides the advantages of comminution with maximum economy for flows from 10 to 15 M.G.D. Screening and cutting of coarse sewage material is accomplished without removal from the flow, maintaining continuous cleaning of the screen. The Barminutor, developed and tested over 5 years, based on 15 years successful experience with the Comminutor, eliminates odors and handling nuisance in the screening process. High rate cutting in the flow—comminution—provides low maintenance cost and long life for cutting parts.

In tests conducted on a Barminutor installed at the Indianapolis, Indiana Sewage Treatment Plant, the unit was subjected to test loads of screenings up to six times normal load for 40 M.G.D. This material was comminuted and the screen completely cleaned in six minutes. Even with this heavy load head loss through the screen did not exceed 6". Just as with the Comminutor, the power requirements of the Barminutor are low.

FUNCTION OF THE BARMINUTOR

1. Cleaning the ¾" vertical bar screen and cutting of the screenings is accomplished by continual travel of the comminuting unit at 8 ft. per minute. Both upward and downward travel is controlled by an electric reversing brake motor.
2. The cutters on the comminuting unit, rotating at 400 R.P.M., travel within slots of the U-shaped bars and carry coarse material to the combs for cutting.
3. The direction of rotation automatically reverses when the direction of travel changes. The combs automatically position themselves to accomplish rapid cutting for each direction of rotation.
4. Uncuttable material is automatically rejected without damage to the cutting parts.
5. Rotation of cutters, position of combs and rejection of uncuttable material is accomplished through oil powered hydraulic system.

Close-up of Cutters and Combs. Cutters rotate within slots of Bar and Comb

*Chicago Pump Company's trade name for its new screening and comminuting device for large sewage flows from 10 M.G.D.

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SEWAGE AND INDUSTRIAL WASTES

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A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

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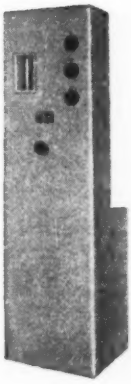

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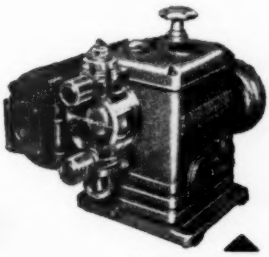

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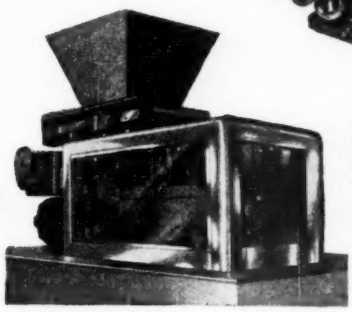

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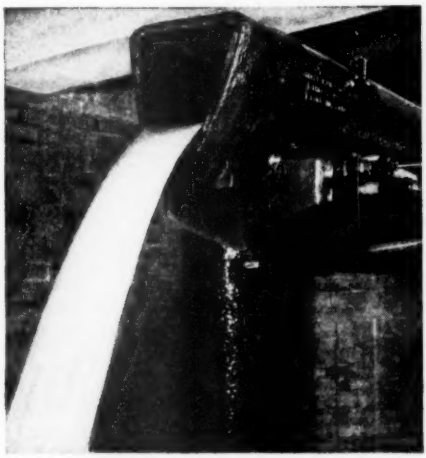

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Association	*Place*	*Time*
Texas Water and Sewage Works Assn.	Texas A. and M. College, College Station, Texas	March 7–12, 1954
New Jersey Sewage and Industrial Wastes Assn.	The Traymore Hotel, Atlantic City, N. J.	March 10–12, 1954
Louisiana Conference on Water Supply and Sewerage	Louisiana State University, Baton Rouge, La.	March 10–12, 1954
Arkansas Water and Sewage Conference	Hotel Marion, Little Rock, Ark.	March 22–24, 1954
Kansas Sewage Works Assn.	Broadview Hotel, Emporia, Kan.	April 7–9, 1954
Arizona Sewage and Water Works Assn.	Santa Rita Hotel, Tucson, Ariz.	April 22–24, 1954
Montana Sewage and Industrial Wastes Assn.	Hotel Baxter, Bozeman, Mont.	April 22, 1954
New England Sewage and Industrial Wastes Assn.	Hotel Somerset, Boston, Mass.	April 22–23, 1954
Maryland-Delaware Water and Sewage Assn.	Hotel Francis Scott Key, Frederick, Md.	April 29–30, 1954
California Sewage and Industrial Assn.	Hotel Senator, Sacramento, Calif.	May 5–8, 1954
Michigan Sewage and Industrial Wastes Assn.	Kellogg Center, Michigan State College, East Lansing, Mich.	May 22–24, 1954
Central States Sewage and Industrial Wastes Assn.	Hotel Leland, Richmond, Ind.	June 24–26, 1954
Pennsylvania Sewage and Industrial Wastes Assn.	The Pennsylvania State College, State College, Pa.	Aug. 25–27, 1954
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Andrew Jackson Hotel, Nashville, Tenn.	Sept. 20–22, 1954
Missouri Water and Sewage Conference	Hotel Governor, Jefferson City, Mo.	Sept. 26–28, 1954

TWENTY-SEVENTH ANNUAL MEETING

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in conjunction with

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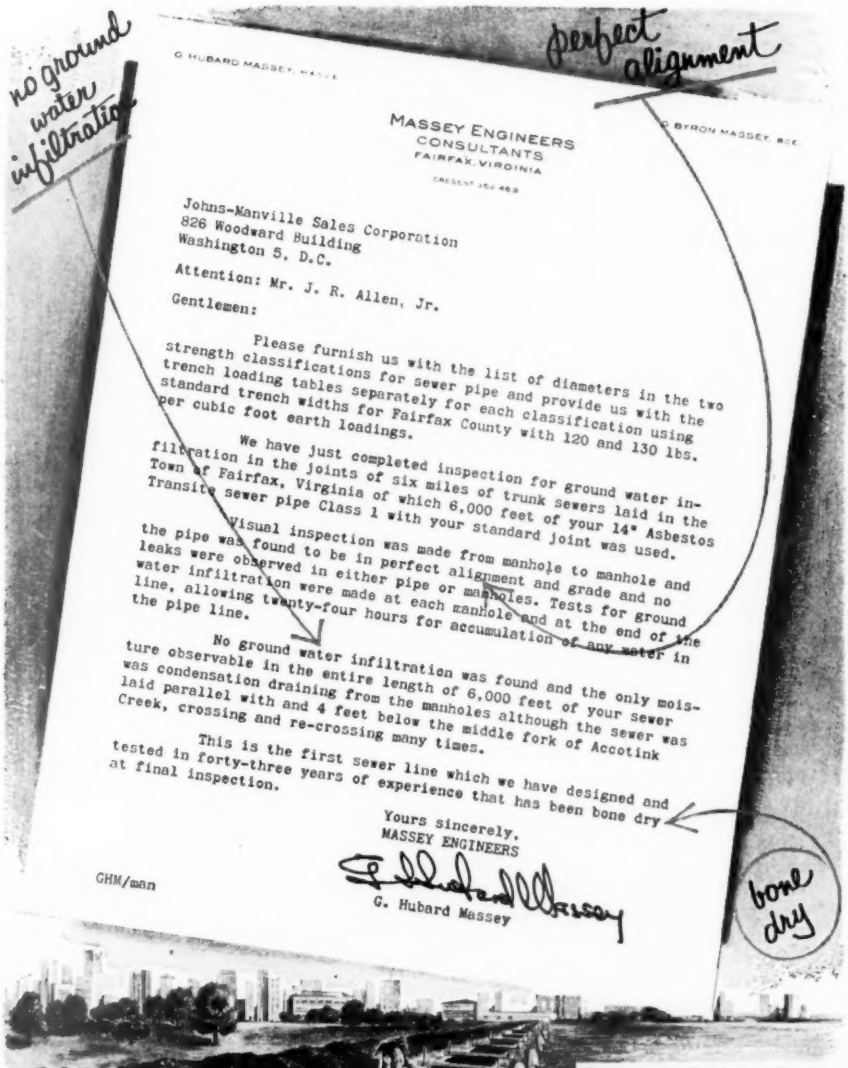
Netherland Plaza Hotel, Cincinnati, Ohio

October 11–14, 1954

Nebraska Sewage and Industrial Wastes Assn.	Keystone Hotel, McCook, Nebraska	Nov. 11–12, 1954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Please furnish us with the list of diameters in the two strength classifications for sewer pipe and provide us with the trench loading tables separately for each classification using standard trench widths for Fairfax County with 120 and 130 lbs. per cubic foot earth loadings.
We have just completed inspection for ground water infiltration in the joints of six miles of trunk sewers laid in the Town of Fairfax, Virginia of which 6,000 feet of your 14" Asbestos Transite sewer pipe Class 1 with your standard joint was used.
Visual inspection was made from manhole to manhole and the pipe was found to be in perfect alignment and grade and no leaks were observed in either pipe or manholes. Tests for ground water infiltration were made at each manhole and at the end of the line, allowing twenty-four hours for accumulation of any water in the pipe line.
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This is the first sewer line which we have designed and tested in forty-three years of experience that has been bone dry at final inspection.
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MASSEY ENGINEERS
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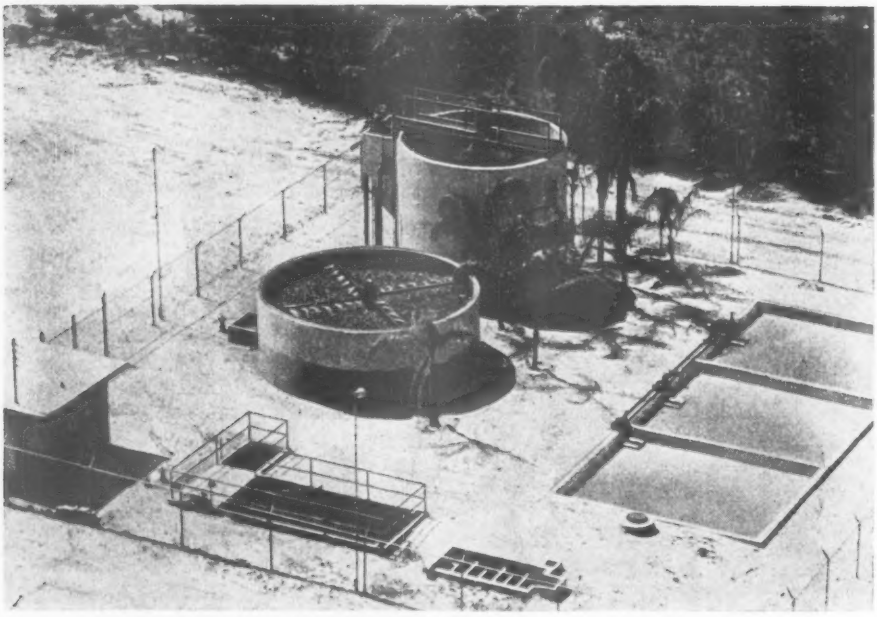
BRIEFS from "THE YEOMANS GUARD"



Yeomans-developed "package" sewage treatment system at Garden Manor, Florida —part of unique pay-as-you-go sanitary system.

Garden Manor, Florida—
ANOTHER YEOMANS SOLUTION TO SMALL-COMMUNITY SANITATION PROBLEMS

Sanitary needs of the small community are no longer of interest only to health officials and sanitary engineers . . . as shown by the following facts concerning the new Yeomans-developed sewage treatment system at Garden Manor Subdivision, St. Petersburg, Florida:

- When the developers of Garden Manor Subdivision offered a complete sanitary system as part of their 800-lot development, home buyers gladly paid premium prices for lots, and agreed to a 20-year tax levy to pay for operation and maintenance of the sanitary system by the city of St. Petersburg.
- When the pay-as-you-go financing employed at Garden Manor was featured in a recent issue of the Yeomans periodical, "The Yeomans Guard," readers across the country demonstrated as much interest in the "package" plant itself as in the unusual financing.

IN THE PUBLIC EYE . . . AND WHY

This growing interest of the general public in small community sanitation needs, as indicated in the case of Garden Manor, stems mainly, we believe, from these factors:

BRIEFS (*CONTINUED*)

1. Steady decentralization of housing and industry, with resulting use of land that is remote from existing sewage treatment systems

2. Increasing disfavor with which health officials view unsanitary septic tanks

3. Increasing public and industrial demand for protection of the economic and recreational values of our streams

THE YEOMANS APPROACH TO THE PROBLEM

The Garden Manor sewage treatment system is one of a series of treatment systems developed by Yeomans to meet the health requirements of all communities in the 50 to 2500 population range; and, at the same time, to be flexible enough to permit specific "tailoring" for the specific requirements of the community to be served.

Each system in the Yeomans small-community series is a "package" in terms of compactness and one-source responsibility. Yeomans "package" sewage treatment systems are not "off-the-shelf" systems as regards size, equipment or operation; nor is a Yeomans "package" system a scaled-down version of a larger one.

The series includes "package" systems for either primary treatment or complete treatment.

The unvarying success of these Yeomans "packages" is a direct result of a determination to develop sewage treatment systems that meet local health requirements as well as the following basic needs common to practically all small communities, new subdivisions, isolated schools, institutions and industrial plants:

- ECONOMY . . . in first cost and in operation
- COMPACTNESS and ATTRACTIVENESS—The odor-free Garden Manor plant with its camouflage painting and palm tree landscaping is a good example. (See cut.)
- TAILORED FOR THE JOB—not a cut-down version of a large-community system
- SIMPLE MAINTENANCE—Highly skilled operating and service men are usually not available, even if the budget would permit
- GUARANTEED SATISFACTION—An iron-clad guarantee that the system will operate successfully in practice as well as in theory

The full Garden Manor treatment system and financing story is covered in the current issue of "The Yeomans Guard;" and complete information on Yeomans "Package" Sewage Treatment Systems is given in a new bulletin. Copies of each, as well as help on specific small-community treatment problems are available on request.

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BROTHERS COMPANY
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☐ "The Yeomans Guard"
☐ New "Package" Treatment System Bulletin
☐ Other information as outlined in attached letter

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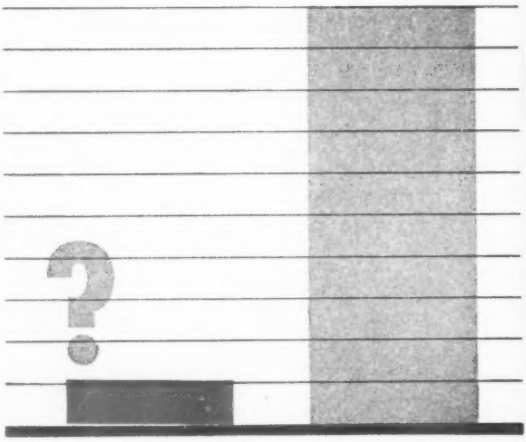
How much should you spend for valve maintenance?

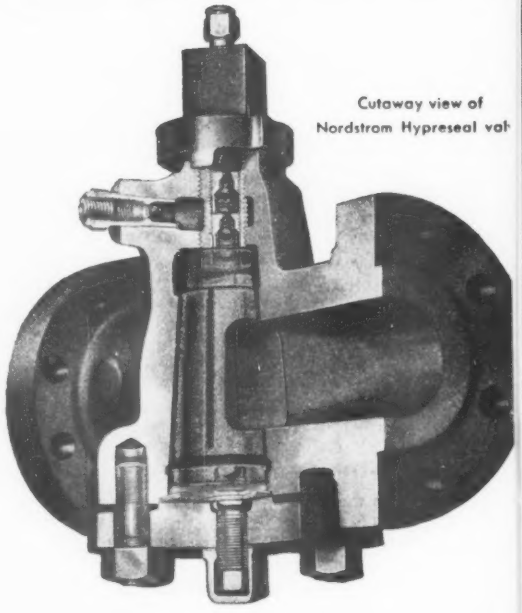
In all but the most simple services, *any* kind of valves need *some* maintenance.

Of course the same thing is true with any mechanism where metal rubs metal. Take your car, for example. You lubricate the engine to *reduce* maintenance and save major repair bills. If you don't lubricate it, you save a few dollars on lubricant, but pay the far, far higher costs of part replacement. More important, you'll need a new car much oftener.

Exactly the same principle applies to valves. If you install Nordstrom lubricant-sealed valves, maintenance is generally confined to adding lubricant at intervals. You lubricate to *reduce* maintenance—to avoid the high costs of major repairs, new parts, and shorter valve life. That's the big advantage of Nordstrom valves in the first place.

Over a 20-year period, Nordstrom sales of repair parts have been less than half of one per cent of sales. In several plants in which records were kept and where Nordstrom and other valves were used, repair parts for Nordstrom valves ran about one-tenth of other makes.





Cutaway view of Nordstrom Hypreseal val

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Second, it *lubricates* so the plug slides without the grinding, galling wear that means high replacement costs.

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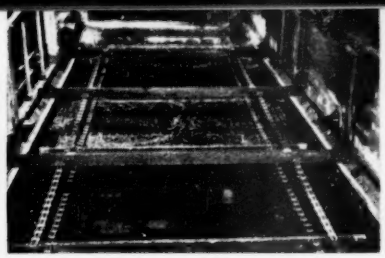
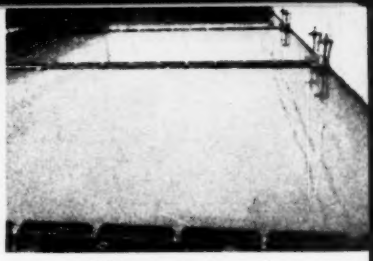
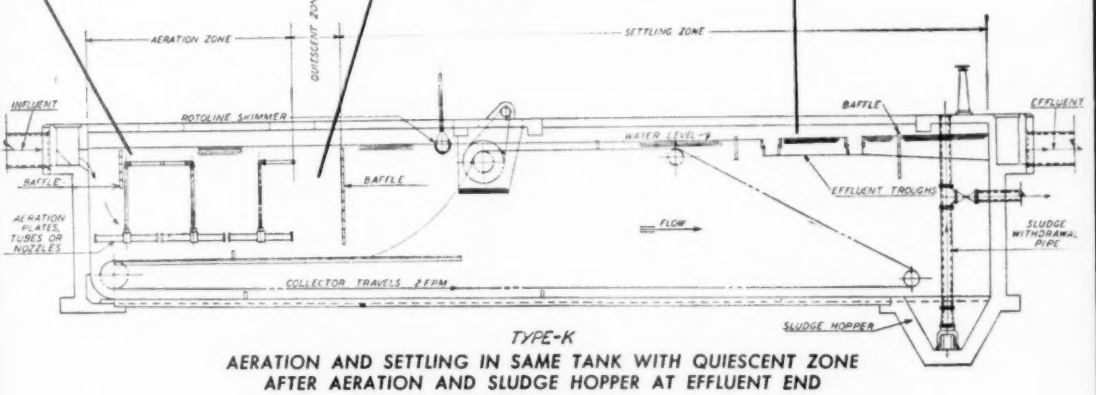


Collector, looking toward influent end from quiescent zone. Slow, uniform speed removes sludge positively with minimum agitation.



Effluent weirs in settling zone of tanks. Suspended solids in the effluent are easily reduced to 45 ppm.



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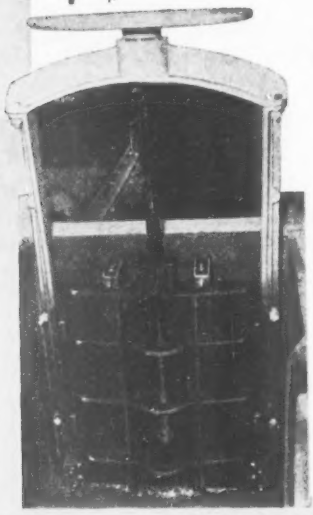

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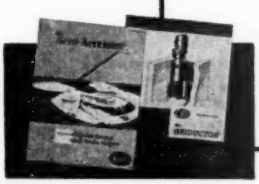

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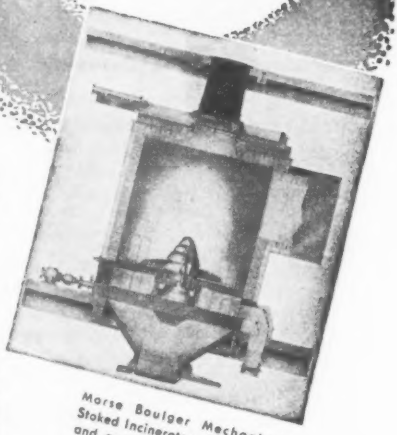

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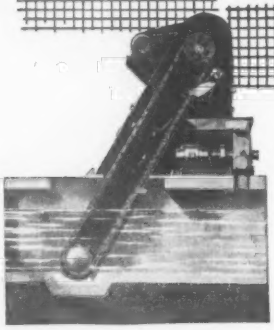

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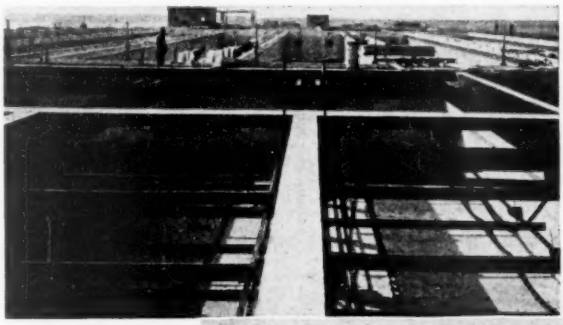

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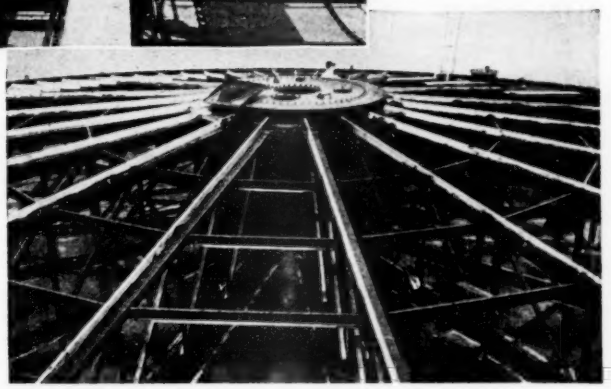

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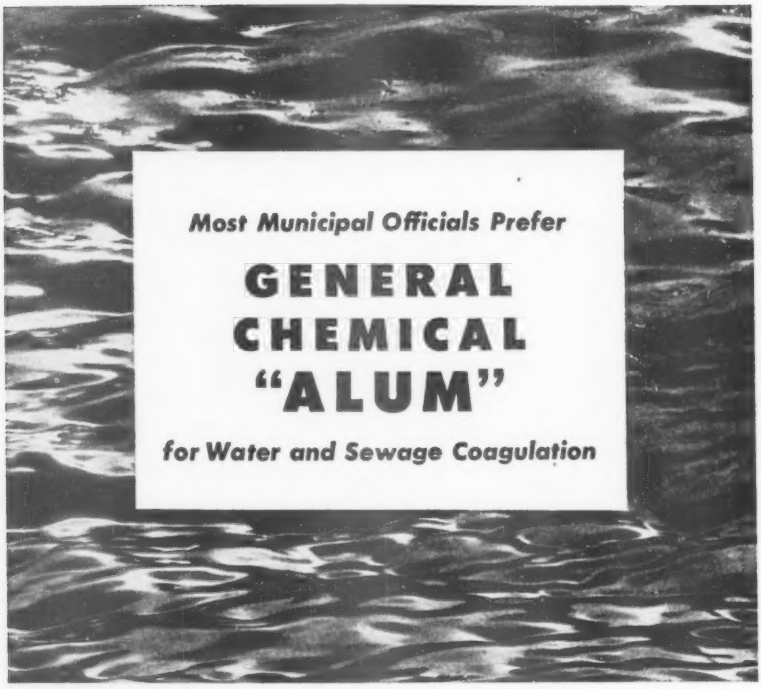

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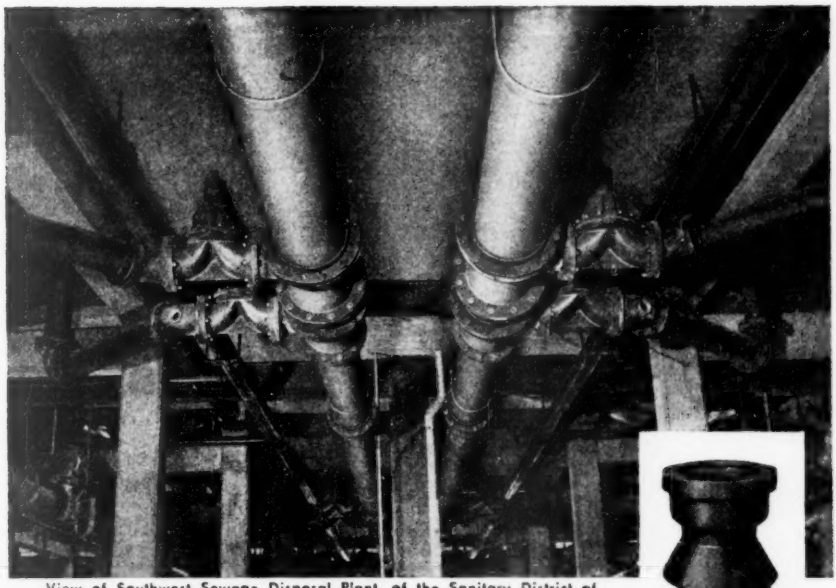

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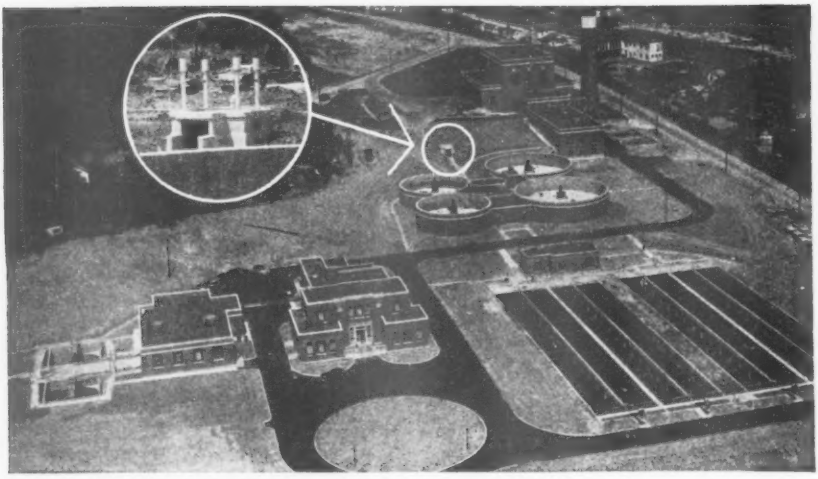

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 26 **February, 1954** **Number 2**

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W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois
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Two major forward steps were taken last spring in Pennsylvania's Clean Streams Program. These new Dorr-equipped treatment plants at Bethlehem and Easton went into operation to play an important part in abating pollution of the Lehigh and Delaware Rivers. Biofiltration and Multdigestion were selected as the most efficient combination at both plants. If you don't already have Bulletin No. 6041, Dorr Equipment and Methods for Modern Sewage Treatment, write for a free copy today. The Dorr Company, Stamford, Conn.

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Sewage Works

PRODUCTIVE RESEARCH IN WASTE TREATMENT AND DISPOSAL: A PROGRAM *

By Harold Allen Thomas, Jr.

Associate Professor of Sanitary Engineering, Division of Applied Science, Harvard University, Cambridge, Mass.

The vast expansion of industry and the marked elevation of standards of living in the United States during the post-war period have brought an intensification of problems of waste disposal and water reclamation on so large a scale as to present an unprecedented challenge to the profession of sanitary engineering. The development of new natural resources, new sources of power, new engineering materials, and new techniques has proceeded at such an accelerated pace as to demand a revitalized and enlarged scope of thinking and doing on the part of its practitioners.

As a primary line of action, more reliance must be placed on the fundamental sciences and less on empirical cut-and-try experimentation. While it is true that in the past advance has largely been the result of chance discovery and experiments suggested by practice, it is now becoming evident that this approach is being affected by the law of diminishing returns. Almost without exception practical methods of sewage treatment are based on principles discovered more than 40 years ago. Progress in the last two decades has been almost exclusively developmental, involving refinements of established processes, principally in the direction of increased mechanization and control. Except for improved gadgetry it would appear that the saturation point for the conventional developmental approach has nearly been reached.

Significant new progress is predicated on a return to the fountainheads of pure chemistry, biology, and physics. In the application of modern techniques and instruments of these sciences, particularly those of physics, lie rich opportunities for sanitary engineering progress.

Recommendations

Five broad avenues of advance are presented in the following outline that, it is believed, will be productive and rewarding. Some specific lines of investigation are noted; these are intended to be suggestive rather than exhaustive.

1. Thorough re-evaluation of indices of pollution and contamination. With the decline of morbidity rates of the enteric diseases, coliform standards have altered interpretative value with relation to probability of infection. For example, with the decrease of the *S. typhosa E. coli* ratio in sewage, less stringent coliform standards would afford the same degree of safety against typhoid fever as present standards did three decades ago. This is not to suggest a relaxation of criteria for coliform density, but rather to advocate a more realistic evaluation of relationships between the hazards of diseases and toxic substances and water quality standards erected against them. New laboratory tools, such as the membrane filter and the spectrophotometer,

* Prepared for and approved by the National Research Council, Division of Medical Sciences, Subcommittee on Waste Disposal, Herbert M. Bosch, Chairman, and approved December 15, 1953, by the parent Committee on Sanitary Engineering and Environment, Abel Wolman, Chairman.

should furnish valuable aids in these investigations.

(a) Continued research on biochemical oxygen demand, coliform, and other similar tests are desirable, but not to such a degree as to exclude a search for newer and more significant determinations.

(b) Better methods and perhaps substances for disinfection of sewage and other contaminated wastes.

(c) A critical examination of the significance of aftergrowths in receiving waters subsequent to disinfection. New bacteriological techniques including microbes tagged with radiotracers or rendered resistant to various specific antibiotics, offer assurance of more definitive results than heretofore attained.

(d) Further delimitation of pathogen survival times. Significant alterations have occurred in the mineral substrate of domestic sewage. The phosphate content has been doubled in a 5 year period; a greater variety of compounds including micronutrient elements, such as iodine, bromine, molybdenum, and boron, have appeared in significant amounts. The assessment of pathogen die-away rates should not be confined to investigations of sewage treatment or polluted waterways, but should be extended to include the lower atmosphere and land surfaces exposed to the vagaries of climate.

2. Added emphasis on methods of evaluating pollution load capacities of streams and concomitantly on improvement in the art of plant design to attain stipulated amounts of treatment.

Here a greater degree of adjustment of objectives and cross-fertilization between engineers and biologists is greatly to be desired.

Only by ascertaining the capacity of a stream to handle pollution at any level of classification and by loading it accordingly, is it possible to apportion its capacity equitably among the various users. In the past, too little thought has been given the matter of proportioning the treatment to needs of the stream.

(a) Improved methods of aeration, possibly with air injection at supersonic velocities.

(b) Application of principles of fluid mechanics to problems of mixing and short-circuiting of flow in tanks and streams. Possibilities in this connection lie not only in higher treatment effieciencies but also in more precise quantitative evaluation of permissible pollutional loads. Radiotracers, such as tritium, may provide the key to practical results.

(c) Development of a satisfactory continuous dissolved oxygen recorder for use in stream surveys.

(d) Centrifugal storm flow separators for combined sewer overflows.

(e) High-rate sludge digestion (anaerobic activated sludge).

(f) Wet sludge incineration in high-pressure tanks.

(g) Model artificial streams to facilitate study of effects of new types of waste in stream ecology.

(h) Use of pure oxygen in sewage treatment.

(i) New processes for control of nitrate and phosphate in sewage plant effluents.

3. More effective and economical waste treatment and disposal methods for small and isolated communities, especially under adverse conditions of climate, soil, and topography.

(a) Investigation of the clogging process in soils by septic tank effluents (possible use of soil conditioners and control of the sodium total ion ratio).

(b) Development of the "completely aerobic" sewage treatment plant for small installations.

(c) Continued investigation of merits of new insecticides, rodenticides, and animal repellents, to delineate further the role of these ancillary aids to sanitation.

4. Search for feasible modifications of industrial processes, in the factory, to reduce amounts of objectionable waste so as to ease problems of trade waste treatment. The atomic energy industry installations afford an outstanding example of accomplishment in this direction.

The implication is that the skills and responsibilities of the sanitary engineer must be fused to those of the chemical engineer to seal discontinuities in formal education.

5. Standardization in the technical literature as to (a) symbols and nomenclature; (b) measuring units, such as loading parameters; and (c) forms of graphical representation; as well as (d) methods of statistical analysis and presentation of experimental results.

The professional language of the sanitary engineer has derived from taproots in widely separated scientific disciplines. At best it has been characterized by many inexactitudes and redundancies of expression. Only by a continuing scrupulous attention to structure will the development of the full potential of a precise and concise technical language be realized.

SEWAGE EFFLUENT DISPOSAL THROUGH CROP IRRIGATION *

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A major problem often confronted in the handling of sewage and industrial wastes is the disposal of the large volumes of waste water. The cost of adequate treatment facilities for most towns and cities is usually high, and even with conventional treatment considerable objection is often raised when the effluent is allowed to enter lakes and streams. The disposal of these waste waters through crop irrigation is being employed, especially by such industries as packing plants, canning factories, and milk plants, which often are not located near a municipality having an adequate treatment and disposal system.

Sewage farming is not new (1)(7)(9). It has been practiced for years in many European countries—England, France, and Germany in particular. Other countries include Australia and India. In the United States, sewage farming has been successfully employed in the warm, arid regions of the southwestern states (4). This climate enables irrigation to be carried on the year around. Also sufficient land can usually be obtained near at hand, yet sufficiently far away from inhabitants so that irrigation with even untreated sewage does not cause a health or nuisance problem. The use of sewage farms for the disposal of sewage or sewage effluent by municipalities in the humid region of the United States has been limited, possibly because (except for special crops) little thought has been given to crop irrigation until recently. Also, in the northern areas, sewage farms can ordinarily be operated only during the summer, necessitating lagooning during the winter months. Even in the southern states where irrigation would be possible the year around, more land per capita would be required than in the arid regions because of the higher rainfall and humidity; however, where studies have been carried on under these conditions, favorable results were obtained (7)(10). On the other hand, the disposal of industrial wastes by means of irrigation is becoming more and more common in the humid region (5)(3) and appears to be especially well suited for industries, such as the canning industries, which are seasonal in operation.

Although the prime objective of most of the industries using irrigation is to get rid of the waste waters, crop yields can and have been increased markedly through well-managed irrigation because of both the additional water and the fertilizer supplied by the waste waters. In contrast, over-irrigation has resulted in killing of the crop, deleterious effects on the soil, and some alleged cases of pollution of nearby shallow wells.

To provide additional information under certain specific conditions with regard to the amount of waste water that can be applied, and its effect on crops, soil, and ground-water conditions, the investigations reported in this paper were carried out.

* A contribution from the Department of Soils, University of Wisconsin, Madison, Wis. Presented at 26th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Miami, Fla.; Oct. 13–16, 1953.

Initial Investigations

Investigations on the disposal of sewage effluent through irrigation from the Oscar Mayer and Company packing plant were begun in August, 1950. The initial investigations were carried out with lysimeters, because much preliminary information can be obtained in this manner with less expense and work than is possible by field irrigation. Also, the lysimeters made possible accurate measurement of the amounts of liquid applied, the amounts used by the crop, and the amounts that percolated through the soil.

Six lysimeters having a depth of 4 ft. and a surface area of 4.36 sq. ft. (0.0001 acre) were constructed of heavy galvanized metal. The lysimeters were painted with aluminum paint to prevent toxicity from the zinc contained in the galvanizing, and were buried upright to within about 6 in. of their open tops near an embankment so that a drain pipe connected at the bottom of each lysimeter could be brought out at the bottom of the embankment, thus permitting collection of the drainage water as percolate. To facilitate uniform drainage, a layer of gravel and then a layer of sand were placed at the bottom. Three lysimeters were filled with Miami silt loam (a mineral soil) and three with peat (a soil containing approximately 60 per cent of organic matter). The soil for this filling was taken in the field layer by layer to a depth of 4 ft., and then these layers of soil were placed in the lysimeters in the same order that they had occurred in the field. These lysimeters, which had been installed the previous year, were seeded to Reed canary grass in the spring of 1950; growth was sufficient to permit irrigation during the first part of the following August. Waste water from the Oscar Mayer and Company packing plant was used for irrigation, following treatment by means of primary settling tanks and trickling filters.

Reed canary grass was grown because it can withstand extremely wet conditions, is a perennial, and grows luxuriantly from early spring to freeze-up, thus making possible utilization of large quantities of water over a long growing season. Two of the lysimeters of each soil type were irrigated with sewage effluent, the remaining one of each soil type with city water. The two lysimeters irrigated with city water served as a check, making possible studies and measurements of the changes in the crop, the percolate, and the soil wrought by irrigation with sewage effluent.

Samples of effluent used for irrigation were taken at the time of each irrigation and the concentration of various ions therein was determined.

The concentration of nitrogen, phosphorus, and potassium in the effluent tended to remain quite constant for different samples taken in any one year, but wide variations did occur from year to year, as shown in Table I.

The relatively low concentrations of the various ions in 1950 can be accounted for by a dilution of the sewage from the packing plant with domestic sewage from a nearby municipal housing project. In 1951 and 1952, the domestic sewage was by-passed to the municipal plant. Concentrations of sodium in the effluent were not deter-

TABLE I.—Average Concentration of Various Ions in Sewage Effluent from Oscar Mayer and Company Packing Plant During the Irrigation Periods

Period	NH_4–N (p.p.m.)	Tot. N (p.p.m.)	P (p.p.m.)	K (p.p.m.)	Ca (p.p.m.)	Mg (p.p.m.)	Na (p.p.m.)
Aug.–Oct., 1950	3.2	10.1	2.0	9.9	—	—	—
May–Oct., 1951	13.7	22.7	8.9	36.9	—	—	—
May–Oct., 1952	25.0	44.9	7.7	19.7	67.9	46.4	680

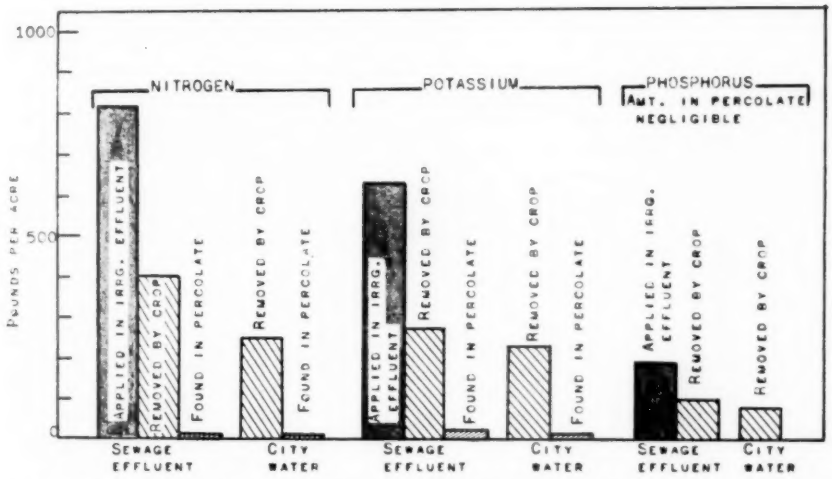

FIGURE 1.—Lysimeters containing Miami silt loam: cumulative amounts of nitrogen, potassium, and phosphorus applied in irrigation, removed by crop, and present in percolate through the growing seasons of 1951 and 1952.

mined in 1950 and 1951. However, because of the large amounts of effluent added to the soil in 1950 and 1951, it was recognized that harmful amounts of sodium might thus be added to the soil. The harmful effects of sodium to soil structure can be ameliorated to some extent by favorable concentrations of calcium and magnesium in the irrigation waters. Therefore, the concentrations of these three ions were determined in 1952; it is apparent from Table I that the sodium concentration is high. According to Wilcox (11) the suitability of water for irrigation can be fairly accurately appraised by determining what percentage of the total cations in the water is represented by sodium according to the following formula, in which cation concentrations are expressed in terms of gram equivalents per million:

$$\text{Percentage Na} = \frac{\text{Na} \times 100}{\text{Ca} + \text{Mg} + \text{Na} + \text{K}}.$$

To be suitable for irrigation, the equivalent precentage of sodium in the water should not exceed 80, nor should the total concentration of cations (in equivalents per million) exceed 25. The comparable values of the effluent used in this study were 79.5 and 37.2, respectively, which indicates that this effluent is not particularly suited for irrigation on most soils. As of September 1953 there has been no apparent deterioration of either soil used in the lysimeters, but it is possible that in time harmful effects may appear.

The effectiveness to which the soil and crop removed nitrogen, phosphorus, and potassium from the effluent that percolated through the soil is evident in Figures 1 and 2. Losses of phosphorus from both soils were so small that they could not be satisfactorily represented in the figures (less than 0.2 lb. per acre was lost from any of the lysimeters over the 3-year period). Only negligible amounts of potassium were lost from either soil. On the other hand, the loss of nitrogen from the peat soil over the 3-year period was appreciable, although only about 3 per cent of this loss occurred during the third year. The disturbance of this soil, which is high in nitrogen, during

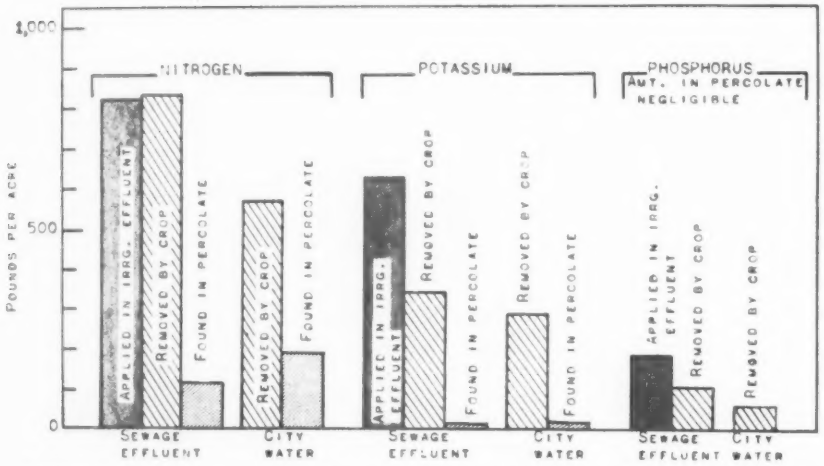

FIGURE 2.—Lysimeters containing peat: cumulative amounts of nitrogen, potassium, and phosphorus applied in irrigation, removed by crop, and present in percolate through the growing seasons of 1951 and 1952.

placement in the lysimeters resulted in better aeration and a proportionately greater mineralization of organic nitrogen. However, after stabilization through settling the losses of nitrogen from the peat soil were no greater than from the Miami silt loam.

It will be noted that only in the case of potassium were the losses slightly greater where sewage effluent was used for irrigation. On the other hand, loss of nitrogen from the peat actually decreased under irrigation with sewage effluent, in spite of the large amount of nitrogen thereby added. Since the peat is low in phosphorus and potas-

TABLE II.—Yields of Reed Canary Grass Grown in Lysimeters Irrigated with Sewage Effluent and City Water and Inches of Percolate and Transpiration Under Different Treatments (1951 and 1952)

Kind of Irrigation Water Applied	1951 Season				1952 Season			
	Liquid (in.)			Yield Dry Matter (tons/A.)	Liquid (in.)			Yield Dry Matter (tons/A.)
	Applied*	Percolated	Transpired and Evaporated		Applied*	Percolated	Transpired and Evaporated	
(a) Miami Silt Loam								
City water	39	13.6	44.9	2.9	50	4.5	65.6	3.2
Sewage effluent	41	13.9	46.6	3.9	54	4.9	69.2	4.3
(b) Peat								
City water	39	9.7	48.8	6.9	64	4.4	80.2	6.4
Sewage effluent	43	8.5	54.0	8.7	69	3.4	85.7	9.7

* In addition there were 19.5 and 20.14 in. of rain during the irrigation periods of 1951 and 1952, respectively.

sium, the larger crop yields made possible by these nutrients being supplied by the effluent resulted in a correspondingly greater up-take of nitrogen by the crop where effluent was used for irrigation.

Water Consumption and Crop Yield

Table II shows that surprisingly large quantities of water were transpired by the crop and lost through evaporation in 1951 and 1952 (18 in. of effluent were applied in 1950, but since irrigation was begun in August, data for that year are not included). Also, variations in seasons resulted in about a 40 per cent greater utilization of water in 1952 than in 1951. The results obtained with field irrigation in 1953 indicate that water consumption under field conditions will be considerably less (though still substantial) than was obtained with the lysimeters (the results obtained with field irrigation in 1953 are discussed in a following section). This difference can be explained by the fact that the grass around the lysimeters was kept short; consequently, sunlight penetrated the foliage not only from the top, but also from the sides, resulting in a much higher absorption of net solar energy per unit area by the crop in the lysimeters than that in the field, where these edge effects are relatively small. In addition, wind movement through the crop in the lysimeters was undoubtedly greater than in the field, where the movement is largely over the surface of the crop.

It will be noted in Table II that yields on both soils were markedly increased by irrigation with sewage effluent. On the Miami soil the increases were brought about by the nitrogen supplied by the effluent. This soil, being a mineral soil, is relatively low in organic matter, and consequently nitrogen. The crop on the peat soil was benefitted by the phosphorus and potassium added, because this soil is low in these nutrients but high in nitrogen, as was previously noted. These conclusions are borne out by the chemical composition of the crop as revealed by chemical analysis.

Effect of Irrigation on Concentration of Various Elements

Irrigation with effluent markedly affected the concentration of sodium in both the soil and the percolate. (Table

TABLE III.—Concentrations of Available Phosphorus and Exchangeable Cations in Soil and in Solution in Percolate in the Case of Peat and Miami Silt Loam Contained in Lysimeters and Irrigated for Three Growing Seasons with City Water or Sewage Effluent

Medium	Type of Irrigation Water Applied	Available P (p.p.m.)	Exchangeable Element			
			P (p.p.m.)	Ca (p.p.m.)	Mg (p.p.m.)	Na (p.p.m.)
(*a*) Miami Silt Loam						
Soil	City water	49	138	1,780	590	12
Soil	Sewage effl.	58	130	1,590	420	545
Percolate	City water	Trace	5.5	137	101	11
Percolate	Sewage effl.	Trace	5.8	1,060	500	843
(*b*) Peat						
Soil	City water	10	35	1,550	660	25
Soil	Sewage effl.	22	34	1,390	550	1,095
Percolate	City water	Trace	4.8	255	139	9.7
Percolate	Sewage effl.	Trace	5.6	560	299	1,410

I shows that the concentration of sodium in the effluent is about 680 p.p.m.) The concentration of exchangeable sodium in the Miami and the peat soils irrigated with city water was 12 and 25 p.p.m., respectively, whereas in the same soils irrigated with sewage effluent it was 545 and 1,095, respectively (Table III). Since sodium is not held as tightly in exchangeable form as other cations, such as calcium, magnesium, or potassium, there was a marked movement of sodium out of the soil with the drainage waters. These high additions of sodium to the soils also increased the movement out of the soil of calcium and magnesium; thus, the concentrations of calcium and magnesium in the percolate from the lysimeters irrigated with sewage effluent was several times higher than that from those irrigated with city water. This is to be expected, because large amounts of sodium added to a soil will tend to displace exchangeable calcium and magnesium; these elements then are subject to loss in the drainage waters. The effect of the sodium on the calcium and magnesium concentrations in the drainage water was also reflected in a decreased content of them in exchangeable form in the soil. These data lead to the conclusion that if the sodium concentration in the soil continues to increase and the concentration of calcium and magnesium continues to decrease, the physical condition of the Miami silt loam, and perhaps of the peat also, will in time be harmed. It should be noted here that the additions of calcium and magnesium to the soils through irrigation were essentially the same whether irrigated with effluent or city water, because both had an average concentration of 70 and 53 p.p.m. of calcium and magnesium, respectively.

The available phosphorus content of the peat soil was doubled by irrigation with sewage effluent, but remained unchanged in the Miami silt loam, due, most likely, to the much higher phosphorus fixing power of the latter soil (removal of phosphorus by the crop was essentially the same for both soils, being approximately half of that applied). The loss of phosphorus to the drainage waters was negligible; the concentration never exceeded 0.05 p.p.m. in the percolate from any of the lysimeters, regardless of the kind of irrigation. The potassium concentration in the percolate from the Miami silt loam was increased about 5 per cent, and that from the peat about 17 per cent when irrigated by sewage effluent. In neither soil, however, was the concentration of exchangeable potassium affected by irrigation with effluent, even though twice as much potassium was added to the soils as was removed by the crops. It is likely that fixation of the potassium by the soil in unexchangeable form was the cause of this, since losses in the drainage waters were exceedingly low.

Investigations with Field Irrigation

On the basis of the information obtained from the lysimeters, plans were made in 1952 to irrigate a 40-acre field located near the sewage treatment plant. A diagram of the field is given in Figure 3. The field is quite level, and the top 2 ft. consists of peat. At present, the field is bordered by drainage ditches. The peat is underlain by a layer of silt, also about 2 ft. in depth, followed by a more sandy material. Before any irrigation had been done, the free water table was at a depth of about 5 ft. depending on variations in surface relief.

After plowing in the fall of 1951, the field was seeded to Reed canary grass. A poor stand of grass necessitated reseeding of the field in August, 1952. To bring the effluent to the field, the drainage ditch bordering the field on the south was dammed with earth near Starkweather Creek. A gated culvert was installed in the dam so that the water in the ditch could be lowered if necessitated by heavy

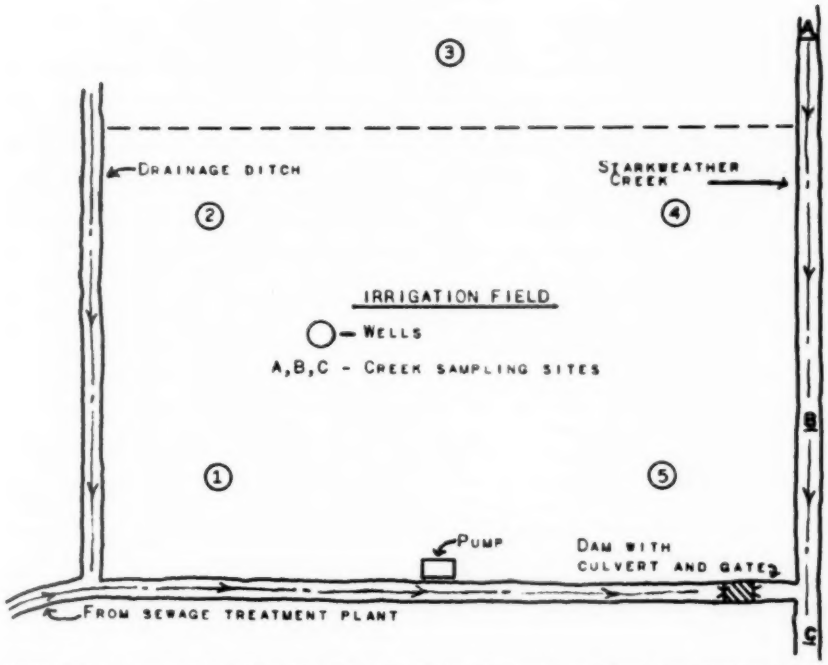

FIGURE 3.—Layout of irrigation field in relation to drainage, showing location of test wells, creek sampling sites, and irrigation pump.

rains and runoff. A portable irrigation unit consisting of a 1,200-g.p.m. pump, 1,040 ft. of 8-in. aluminum main and two 6-in., aluminum wheel-move laterals each 1,140 ft. long, was used. In order to determine the amount of effluent let into the ditch, a 10-in. water meter was installed in the pipe leading to the ditch from the treatment plant. Also, another 10-in. meter was installed in the main irrigation line near the pump so that the actual quantity of effluent pumped on the field could be measured.

In 1952, the field was irrigated sparingly in order to help the seeding, with no attempt being made to determine the maximum quantities of effluent that could be applied. Irrigation was begun June 15, and continued until November 5, being interrupted for reseeding. During that period, 17.9 in. of effluent were applied over the 40 acres (a total of 2,597,100 cu. ft.).

During the irrigation period, samples of water were taken several times from Starkweather Creek for chemical analysis and coliform counts to determine whether irrigation with effluent had any influence on the chemical content or the microbiological population of the creek waters. The samples were taken at three sites, namely, upstream from the irrigated field, along side of the field, and downstream from the field. There was no indication that irrigation of the field with sewage effluent affected either the chemical or microbiological properties of Starkweather Creek in 1952.

In 1953, water samples were taken from the creek at weekly intervals. In addition, samples were taken from four wells sunk in the irrigated field to a depth of about 3 ft. below the surface of the water table. By means of the wells it was possible to measure changes in the depth of the ground

water, the chemical content, and the coliform count, as caused by the irrigation with effluent. For comparison, a fifth well was sunk in the field north of the irrigated field and beyond the influence of the irrigation. Each well was sterilized with calcium hypochlorite, 12 g. being added to each well and a large plunger being used to insure thorough mixing of the hypochlorite with all of the well water. The wells were pumped out the following day and washed with city water until no trace of hypochlorite remained.

Irrigation was begun on May 15. Up to September 16 (irrigation was to be continued until the soil froze), a total of 37.4 in. of effluent (5,423,000 cu. ft. had been applied to the 40 acres. This is an average of 0.3 in. per day. In addition, there were 15.4 in. of rain during this same period. The water level in the wells indicated that the water table was within 1 ft. of the surface during most of the summer, and during the latter part of July was actually at the surface. Irrigation was withheld for two weeks to allow the water table to recede.

Although the rate of irrigation was at a much higher than optimum rate for the crop, it did make possible the determination of the maximum amounts of effluent that could be disposed of on this particular field. Also, it seems logical to assume that any influence of the irrigation on the coliform numbers and the chemical content of Starkweather Creek and the ground water would be accentuated. This information is of considerable importance, because in any cause of over-irrigation with sewage effluent or industrial wastes, its effects on ground and surface waters should be known.

The chloride content in Starkweather Creek proved to be the most sensitive measurement of changes in its composition wrought by the irrigation. Of the other elements determined (N, P, Ca, Mg, K, and Na) only the sodium concentration in the creek waters was affected by irrigation, and to a much lesser extent than that of chlorides. The samples taken from the creek at a point alongside of the field (site B) indicate that seepage waters from the field were not entering the stream to any appreciable extent upstream from this point. However, farther downstream there was some evidence that the drainage waters from the field were entering the creek during the latter part of the summer, since the chloride content increased from about 5 p.p.m. at site A (upstream and beyond the influence of irrigation) to about 14 p.p.m. below the field (site C).

Although the chloride content of the creek waters indicated that seepage water from the field was entering the creek during the latter part of the summer, the coliform index did not similarly increase (compare site A with site C, Figure 4). Only on the sampling date of August 31 was the index substantially higher (over 100,000) at site C, and this can be explained by the fact that the culvert gate in the dam sprang a leak, thus allowing a small amount of effluent from the irrigation ditch to enter the creek. This condition was corrected as soon as observed. Although it will be observed in Figure 4 that on three separate dates—namely, June 15, July 15, and August 5—the coliform index at site B (along side of field) appeared to be increased by irrigation, it is not believed that this was caused by seepage water from the field, but rather by spray from the sprinkler heads being blown directly into the creek, since the sprinkler lines were near the creek on these dates.

The effectiveness of the soil in reducing the coliform numbers (and presumably, that of the pathogenic organisms as well) of the effluent percolating through it was revealed by the indices made on the well waters. The coliform indices of the well water were generally 10 or less, and except for well 5, which had an index of 10,000 on September

9, never exceeded 100. In most cases, when the index exceeded 10 there had been standing water around the well. The wells were pumped dry after each sample was taken; it is possible that in these instances some of the water in the well had seeped down alongside the well casing and up into the well without passing through the soil. This, of course, could account for the increased numbers of coliform, as this effluent would not have been subjected to the filtering action of the soil.

When considering the high coliform index of the effluent as it came from the treatment plant (about 10,000,000 per 100 ml. of effluent), and also the heavy rate of irrigation, it is surprising that the soil was so effective in purification of the percolating waters. It can be assumed that the numbers of pathogenic organisms would be similarly reduced (because of the difficulty of making accurate counts, no attempt was made to determine the kinds or numbers of pathogens present), since it is known that most pathogens do not persist in the soil as long as do the coliform bacteria (8). Also, since the coliform bacteria are found in preponderantly greater numbers in contaminated waters than the pathogenic organisms, the danger of contaminating ground water with the pathogenic types, even with relatively heavy irrigation of effluent, seems quite remote; moreover, it has been demonstrated that considerable numbers of a pathogenic organism are needed to bring about an infection (2)(6).

Summary

The utilization of sewage effluent for crop irrigation and fertilization was studied over a 3-year period by means of lysimeter and field irrigation. The purpose of this study was to determine how much effluent could be disposed of through irrigation, the benefits to

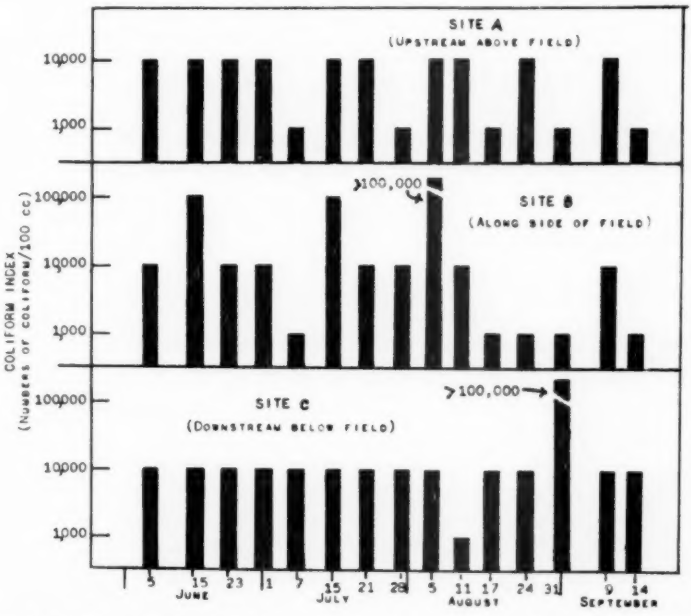

FIGURE 4.—Coliform index of Starkweather Creek at three sampling stations. (Coliform counts made by State Hygiene Laboratory, University of Wisconsin.)

the crop of both the additional water and fertilizer supplied by the waste waters, and the effect of irrigation with effluent on the chemical content and microbiological population of the percolating waters.

The results of these studies can be summarized as follows:

1. In the area under study, 40 in. or more of sewage effluent can be applied to a crop of Reed canary grass during the growing season, weather conditions being normal. Reed canary grass was the only crop studied; however, it is likely that less effluent could be applied to crops that grow over a shorter period, or are not as tolerant to wet soil conditions.

2. The crop and soil are effective in removing virtually all of the nitrogen, phosphorus, and potassium from the percolating waters. When there is a high concentration of sodium in the effluent the losses of calcium and magnesium to the percolate are increased. If too much calcium and magnesium is lost and if the sodium continues to accumulate in the soil the physical condition of the soil will be harmed.

3. The crop yields were substantially increased by plant nutrients in the effluent. The increases amounted to about 1 ton per acre on Miami silt loam (a mineral soil) and to about 2 tons per acre on peat (a soil high in organic matter).

4. Drainage waters from the soil irrigated with sewage effluent did not increase the coliform index of the nearby creek. However, the chloride and to a lesser extent the sodium content of the creek waters was increased. The effectiveness of the soil in reducing the coliform numbers of percolating waters was substantiated by analysis of the ground water. The coliform index, except in one instance, never exceeded 100, in contrast to an index of about 10,000,000 in the effluent applied to the soil.

Acknowledgments

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References

1. Baker, M. N., "British Sewage Works and Notes on Sewage Farms of Paris and on Two German Works." Eng. News Pub. Co., New York, N. Y. (1904).
2. Crawford, A. B., and Frank, A. H., "Effect on Animal Health of Feeding Sewage." *Civ. Eng.*, **10**, 495 (1940).
3. Dennis, J. M., "Spray Irrigation of Food Processing Wastes." THIS JOURNAL, **25**, 5, 591 (May, 1953).
4. Ehlers, V. M., "Experiences with Sewage Farming in Southwest United States." *Amer. Jour. Pub. Health*, **25**, 119 (1935).
5. Mather, J. R., "The Disposal of Industrial Effluent by Woods Irrigation." *Trans. Amer. Geophys. Union*, **34**, 2, 227 (Apr., 1953).
6. McCollough, N. B., and Eisele, C. W., "Experimental Human Salmonellosis. I. Pathogenicity of Strains of *Salmonella meleagridis* and *Salmonella anatum*. Obtained from Spray-Dried Whole Egg." *Jour. Infect. Dis.*, **88**, 278 (1951).
7. Mitchell, G. A., "Observations on Sewage Farming in Europe." *Eng. News*, **106**, 66 (1931).

8. Norman, N. N., and Kabler, P. W., "Bacteriological Studies of Irrigated Vegetables." THIS JOURNAL, **25**, 5, 605 (May, 1953).

9. Roechling, H. A., "The Sewage Farms of Berlin." *Ind. and Civ. Eng.*, Minutes of Proc., **109**, 2570, 79 (1892).

10. Stokes, W. E., "Effect of Irrigation with Sewage Effluent on Yield and Establishment of Napier Grass and Japanese Cane." *Jour. Amer. Soc. Agron.*, **22**, 6, 540 (1930).

11. Wilcox, L. V., "The Quality of Water for Irrigation Use." U. S. Dept. Agr. Tech. Bul. 962, p. 1 (1948).

DISCUSSION

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The history of crop irrigation at Seabrook Farms, Bridgeton, N. J., dates back to 1900 when 3 acres of land were under the overhead type of irrigation. As the acreage was increased, irrigation was added until in 1953 there are about 200 acres of overhead irrigation that have been in use for more than 30 years. In addition, there are now 3,500 acres being watered by portable-type irrigation.

In earlier years, nearby stream and pond water was used. Now, however, most of the overhead installations use the vegetable processing waters, although in areas too remote to have access to waste water, water is drawn from streams, ponds, and a few deep wells.

The problem of disposing of some 10 m.g.d. of vegetable processing waste water became a serious matter for Seabrook Farms Co. when, in 1944, they were ordered by the New Jersey State Department of Health to install treatment facilities in order to abate stream pollution. It was a rather complicated and controversial subject as to the proper and economical method of treatment.

A study was made in 1949 by the installation of three pilot plants comprising (a) chemical coagulation, (b) a standard-rate deep filter, and (c) a high-rate filter. Tests showed the last to be the most efficient. A preliminary design and cost estimate by consulting engineers on a high-rate filter plant to handle 10 m.g.d. showed the cost to be $1,750,000. This was in the early part of 1950.

The only other method of waste disposal that had not been considered was spray irrigation. Therefore, tests were made on a plot of sandy loam adjacent to a wooded area some 2 mi. "down-stream" from the industrial waste screen and pump house. This plot had a good stand of crimson clover cover crop. After applying 2 in. of water, puddling and runoff were encountered in this field. However, due to a matter of bad adjustment, the spray nozzle had been located so that a portion of the spray fell into the woods. There was no puddling there.

The spray nozzle was then relocated in the woods and the ground absorbed more than 100 in. of water continuously applied. This was a feasible solution.

A 10-ft. wide ditch was dug from the effluent of the chlorine contact tank at the treatment plant to the wooded area, a total of 9,000 ft. A Parshall flume was installed in this canal just before reaching the first pumping station for the purpose of checking the quantity of water to be irrigated. Three pumping stations were located at convenient points in the canal, with two turbine-type pumps at each station. A third pump has since been added at the first station for emergency use. The time from testing and construction to operation was about 40 days, and for

the more reasonable sum of about $150,000.

Operation

Each pump supplies a portable irrigation pipeline with 12 giant spray nozzles in fixed positions on each line. Each nozzle consists of a 1/8-in. main orifice and a 13/32-in. minor orifice, the spray covering a circular acre. Therefore, there is a total of 84 acres under irrigation in the 200-acre woods.

In actual operation, each acre receives an application of water for 8 hr. then is rested for 24 hr. The amount of waste water sprayed on an acre varies from 0 to more than 1,200 in. per year.

What are the effects of all this water?

First, there are visual effects: those seen above the ground. Some pictures were taken of the trees and other vegetation in many places in the woods before any spraying was done. Photographs of the same places taken later in the same season show a very lush and abundant growth, particularly the weeds and grasses. This has occurred in each season.

There seems to be no evidence of soil clogging. Pooling and run-off are practically nil. The presence of 425 p.p.m. of sodium in the waste water from sodium chloride used in the process of vegetable preparation does not affect the absorption of the soils, probably due to the pH of 5.50 to 6.00 of this water. In fact, the absorption power has improved.

Secondly, the effect of the quantity of water on the ground-water reservoir is closely checked. Ground-water levels are determined every two weeks in more than 40 test wells driven in various places throughout the area. The rise and fall of the water table is in direct relation to the quantity of water applied to the surface.

Thirdly, there are the quality effects. Chemical and biological tests were made on the ground water from three of the test wells during the first (1950) season. Since then, 18 to 21 wells have been checked weekly. Tests made in 1952 showed that the waste water is purified to practically potable water quality in the first 3 in. of soil, which is of the Sassafras loamy sand type.

TABLE I.—Plant Effluent Characteristics

Year	Av. or Max.	Flow (m.g.d.)	B.O.D.	
			(p.p.m.)	(lb.)
1950	Av.	6.000	191	9,000
	Max.	11.875	1,050	61,950
1951	Av.	5.78	312	10,000
	Max.	10.68	645	27,400
1952	Av.	4.45	121	5,150
	Max.	10.00	380	10,500

The average dissolved oxygen of the waste water as applied to the soil was 1.10 p.p.m. and the nitrates 0.30 p.p.m. There is a slight reoxygenation by the spray, but the source of the nitrates is the soil washed from the vegetables.

The results of quality tests made during the 1950, 1951, and 1952 operating seasons of from May 1 to December 15 are given in summary in Tables I and II. Table III gives the applied pounds B.O.D. per acre per day on the spreading area.

Other operational experiences may be of interest.

Chlorination has been used to control odors in the canal and woods. The chlorine is used intermittently, averag-

TABLE II.—Characteristics of Water in Test Wells

Year	No. Det.	Av. or Max.	B.O.D. (p.p.m.)	Diss. Oxygen (p.p.m.)	Nitrates (p.p.m.)
1950	3	Av.	0.75	7.85	5.70
		Max.	2.50	8.75	13.50
1951	21	Av.	3.80	5.40	1.50
		Max.	6.15	6.15	4.90
1952	18	Av.	2.00	5.20	2.70
		Max.	23.40	9.80	20.00

TABLE III.—B.O.D. Loading on Spreading Area

Year	B.O.D. Applied (lb./acre/day)	
	Av.	Max.
1950	276.00	2,110.00
1951	220.00	1,367.50
1952	117.50	540.00

ing about 500 lb. per day. During the beet season the red color is bleached out of the waste water, using 5,500 lb. of chlorine per day. Lime is fed into the system prior to chlorination to neutralize the acidifying effect of the chlorine and to maintain a chlorine residual to the end of the canal.

The turbine pumps are removed for general repairs after each season. The spray nozzles are lubricated weekly and operate with little difficulty. Corn silk is the only thing that clogs them.

The Parshall flume previously referred to has indicated a seepage loss in the canal for about the first three or four weeks of each season. It also checks the amount withdrawn from the canal for crop irrigation.

There is a crop irrigation pumping station located about half-way down the canal. From this pumping station, 140 acres of overhead-type and about the same area of the portable-pipe-type irrigation are served. The former type has an application rate of 1 in. in 6 hr. The portable spray nozzle tip of 5/32-in. size applies water at a rate of 1 in. in 2 hr., over an area of 0.028 acre per nozzle. In other areas of the vast Seabrook operation, the giant spray nozzles or the foregoing smaller nozzles are used, depending on location and pump capacities.

No attempt has been made to compare the results of using fresh or surface water with waste water on crop yields. It is quite obvious that adding much-needed water to plants will make a vast difference in yield.

Neither is it known what effect the waste water has on soil fertility. Here, again, it is obvious that the plants get some benefit from the nitrogen compounds in waste water. This also refers to the previously mentioned visual effects in the wooded area.

Conclusion

The Seabrook Farms Co. waste-water disposal method has two distinct advantages: (a) a source of water for crops, and (b) re-charging of the ground water from which the original water used in the processing plant is taken. To date the system has worked beyond the most optimistic hopes entertained in 1950. Constant watch and check is kept, of course, for any possible mishap, but there has been no evidence of any harmful effect on any potable water (wells) in the immediate vicinity of the spreading area.

This method has been a happy solution to the company's waste disposal problem. However, it may be well to point out that, before others try this method, the soil should be carefully examined with reference to its ability to absorb, and the ground-water level should be ascertained to find out the capacity of such a reservoir. Actual tests give the best answers and may save much difficulty later.

A NEW CONCEPT IN TRICKLING FILTER DESIGN *

By Bruce Gerber

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A very wide range of treatment efficiencies is attainable through the agency of the trickling filter process. It is practically impossible, however, for the sanitary engineer to design a filter for a specific efficiency, due to the absence of quantitative data showing the inter-relation of the various variables affecting filter efficiencies and over which the designer has control. The lack of such data and a rational method of filter design which takes into consideration all variables known to affect filter efficiencies has done much to narrow its field of application and retard its development.

Operational Factors

The literature contains many references and generalizations on the physical, chemical, and biological mechanisms involved in trickling filter processes thought to be responsible for the reductions in organic matter or B.O.D. through biological beds.

To summarize, the process is considered to be dependent on the intimate contact of applied sewage with the biological slimes covering the filter media and on the transfer of the organic material contained in the applied waste to the biological slimes. All transfer processes across stagnant films such as air, water, etc., are dependent on time—that is, the greater the time of contact, the greater the quantity of material transferred. The designer has direct control over contact time by the proper manipulation of hydraulic rate of waste application and filter depth. It is generally recognized that filter efficiency varies directly with filter depth and inversely with hydraulic loading.

Secondary to contact time in determining the extent or quantity of organic material transferred from the applied waste to the biological growths of a filter bed is concentration or strength of the applied waste. Experience with both low- and high-rate filters has shown that, all other things being equal, weak sewages are conducive to low treatment efficiencies; strong sewage, to high treatment efficiencies. Such a phenomena has various analogies in heat transfer and temperature gradients, fluid flow and pressure differential, flow of electricity and voltage drop. Although the designer has little or no control in fixing the strength of waste applied to a filter except to a limited extent where recirculation is employed, it is one of the measurable variables affecting filter efficiency which must be fully appraised and evaluated to develop the full potential of the trickling filter process.

Other measurable variables affecting filter treatment efficiencies are waste characteristics and temperature. The constituents of a sewage applied to a filter must be of a nature suitable for utilization by the biological organisms as a food. Otherwise, their life processes slow down or cease altogether, with accompanying decreases in treatment efficiencies. Temperature appears to control the relative activity of the organisms instrumental in affecting re-

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duction in B.O.D., and plays an important role in the efficiency of any trickling filter process. A measure of the availability of the organic material in an applied sewage to the organisms inhabiting a filter bed is available in the B.O.D. reaction rate constant. This constant, K_1, although primarily a property of the waste, is to a considerable extent determined by the activity of the organisms, which in turn is largely determined by waste temperature. Since the variation of K_1 with temperature has been fairly well established, the designer of a trickling filter has available to him a parameter which he can utilize to evaluate the availability of an applied waste to the organisms in a trickling filter and also the influence of seasonal temperature changes on treatment efficiencies. This constant is also of value in comparing, relating, and estimating the treatability of various sewages.

Current Design Basis

Most filters are designed on a B.O.D. loading basis—that is, so many pounds of B.O.D. per cubic yard, cubic foot, or acre-foot of filter media. This method of design, while of some use, has been found wanting in many respects, to the detriment of filter development and utilization. Many persons have published data on how B.O.D. loading, hydraulic loading, filter depth, temperature, etc., separately affect filter efficiency, but how filter efficiency is dependent on the inter-play or combination of these variables has not been demonstrated. No trickling filter process, its operation, or its efficiency can be completely defined on the basis of one design variable or loading.

Proposed Design Basis

One method of combining the measurable variables presently recognized as important to the control of trickling filter processes, and demonstrating how the combination of these various variables affect filter efficiencies, is by the use of the dimensionless product as shown on Figure 1. In one curve the relationship is shown between filter efficiencies ranging from about 90 to 60 per cent for a filter operated at hydraulic rates of waste application ranging from 3.68 to 16.39 m.g.a.d., filter depths varying from 2 to 7.25 ft., B.O.D. loads varying from 375 to 8,175 lb. per acre-foot, and temperature variations from 69° to 75° F.

The components of the dimensionless product used, $H/D\ K_1$, consists of the hydraulic dosing rate, H, in feet per day; depth of filter, D, in feet; and the B.O.D. reaction rate constant, K_1 in units of 1/day. Reductions in B.O.D. across the filter for any specific value of the dimensionless product are expressed as a ratio of B.O.D. at depth D to the B.O.D. applied, all in parts per million. For low values of the dimensionless product—that is, low hydraulic dosing rates, moderate filter depths, and high temperatures—treatment efficiencies are at their maximum and the data are well grouped. For high values—that is, high hydraulic loadings, shallow depths, and low temperatures—treatment efficiencies decrease and the data tend to spread out, indicating possibly short circuiting.

Up to dimensionless products of 50 the relationship appears to be linear, with treatment efficiencies varying inversely with increasing values of the dimensionless product. Above values of 50 there is some evidence to indicate increasing efficiencies with increasing values of the dimensionless product, but the data are not sufficient to support such a conclusion. It should be noted that the curve is continuous, even though it is based on data representing filter operation in both the low- and high-rate ranges, indicating that for all practical purposes treatment mechanisms at work in both processes are equivalent.

The data used in this study are the

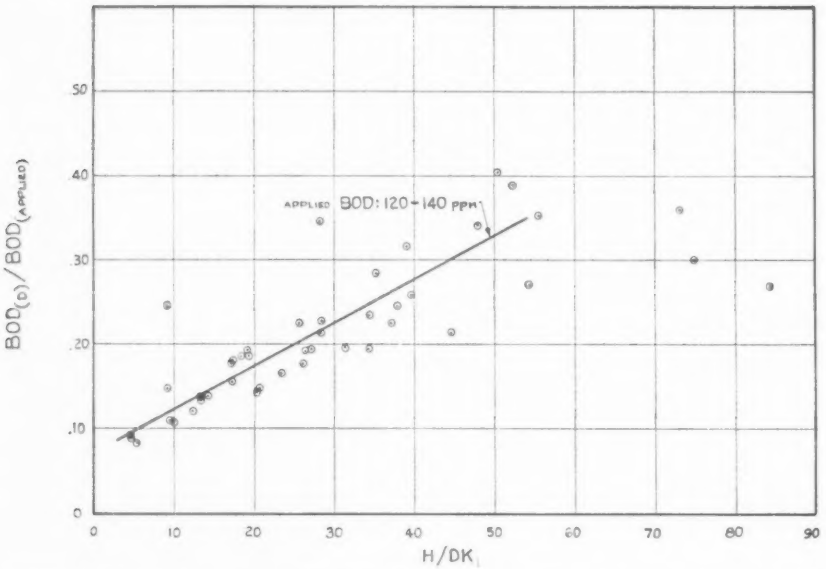

FIGURE 1.—Relationship between trickling filter efficiency and a dimensionless factor involving hydraulic loading, filter depth, and B.O.D. reaction rate.

published results of tests made at the Back River sewage treatment plant in Baltimore, Md. (1). The media used in the filters at this plant consists of trap rock varying in size from 1 to 1½ in. The sewage applied to the filters during the tests varied in strength from 120 to 140 p.p.m. B.O.D., approximately equivalent to a normal raw settled sewage. All efficiencies were based on reductions in B.O.D. obtained solely through the filters operated without recirculation. In the absence of a measured value for K_1, a value of 0.2 per day at 20° C. was assumed; variations in K_1 with temperature were computed from the equation $K_T = K_1 (1.047^{T-20})$. Test results from the Baltimore plant were used because they were considered to be the most accurate and comprehensive trickling filter studies available.

The relationship shown in Figure 1 between filter efficiencies and the combined variables in the dimensionless product should be valid for trickling filters of all rates not utilizing recirculation and having filter stone sizes equivalent to those used at Baltimore, if the assumed value of 0.2 for K_1 at 20° C. is correct. The curve will simply be displaced to the right or left if the value of 0.2 is in error.

It also should be recognized that the curve shown in Figure 1 only applies to waste strengths varying from 120 to 140 p.p.m. B.O.D.; other similar curves will have to be developed for other waste strengths and filter stone sizes.

It remains to be conclusively demonstrated, however, that the constant K_1 in the dimensionless product can be used to correlate the performance of different filters treating various type sewages, even though it has been assumed by various investigators to possess the property by which the treatability of different wastes can be related. If this can be proven, it should then be possible to develop a complete set of curves for any one filter which would apply to all sewages and all filters in general. The same manipulation of data is possible for

filters utilizing the recirculation feature.

The use of the dimensionless product in combining variables is not new to the field of engineering; it has had considerable utility in the field of fluid flow and heat transfer. The Reynolds, Grashof, and Prandtl numbers are familiar to all engineers. The great number of variables with which the sanitary engineer must cope in sewage treatment processes necessitates the use of such means to develop rational methods of design. Simple elaboration on the mathematical manipulation demonstrated should make it possible to take most of the guesswork out of all trickling filter design and thereby facilitate the full development of a dependable process that has been long overdue.

Reference

1. Keefer, C. E., and Meisel, J., "Remodeled Trickling Filters Exceed Expectations at Baltimore." *Water and Sew. Wks.*, **99**, 277 (1952).

HIGH-RATE FILTER CONSTRUCTION COSTS

By Bruce Gerber

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The construction cost of a high-rate filter is dependent on its size, its depth, the terrain on which it is located, the mechanical apparatus used for waste distribution, etc. For sewage filters having depths ranging from 4 to 6 ft., 1953–54 prices run from approximately $32 per cubic yard of filter media for the larger installations to about $100 per cubic yard for the smaller ones. Variations in filter costs with filter capacities are shown on Figure I, based on engineering estimates and construction bids. This curve is based on the Associated General Contractor's Construction Cost Index of 100 in 1913. Present-day costs should be trended from values on this curve by the use of present cost indices.

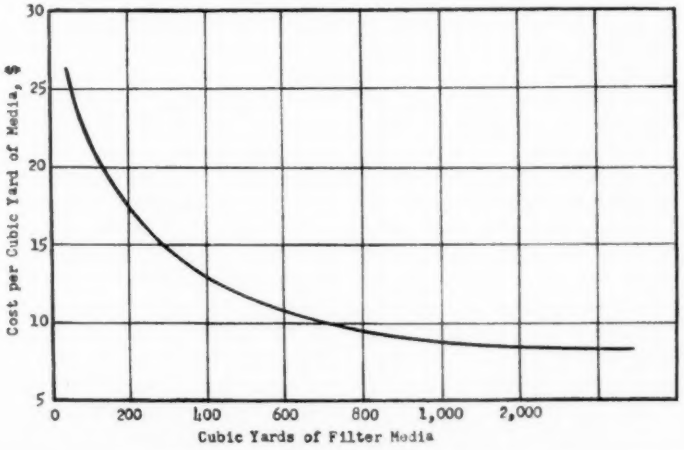

FIGURE 1.—Filter costs based on A.G.C. Construction Cost Index: 1913 = 100.

DUAL DISPOSAL OF GARBAGE AND SEWAGE AT RICHMOND, INDIANA *

By W. E. Ross

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The Richmond, Ind., sewage treatment plant was constructed in 1935–6. It is of the activated sludge type, with separate sludge digestion. Selection of this type of treatment resulted from the fact that the flow in the East Fork of the Whitewater River is comparatively small at best, and at times is so low that a very high degree of treatment is required. At present the flow through the plant often exceeds the flow in the river; on some occasions it is twice the flow in the river. Another factor of importance was that inasmuch as the plant furnishing the electric power was municipally owned, the power cost would simply be a transfer of funds from one municipal department to another.

The plant as originally designed had the following capacities: Grit collection units, 12 m.g.d.; primary units, 9.15 m.g.d.; areators with 10 per cent return, 7 m.g.d.; final clarifiers, 1,190 g.p.d. per square foot overflow rate at 7 m.g.d. and a 30 per cent return; and sludge digesters, 3.65 cu. ft. per capita for 40,000 population. By the end of 1944 it was evident that the capacity of the plant was being reached and it became increasingly difficult to maintain a high degree of treatment. By 1948 the entire plant was so badly overloaded that it was no longer possible to keep the river in good shape below the plant in periods of low flow.

This failure of all but the grit units was evidenced by a drop in the efficiency of the primary units from a 50 per cent removal of solids in 1942 to 19.0 per cent removal in 1947, with a corresponding decrease in the removal of B.O.D., and by a drop in the gas production from 8 cu. ft. to 3 cu. ft. per pound of volatile solids added in 1950. Along with this reduction in the destruction of the volatile solids, an increasingly poor supernatant was produced by the digesters. In addition comparison of the water pumpage rates and the sewage flows indicated that the average daily overflow of sewage given only primary treatment at a very low efficiency was in excess of 1 m.g.d. by 1950.

It should be pointed out that the flows shown in the tables are all based on the sewage flows entering the aeration units and do not show the amounts of flow by-passed at the grit chambers or immediately following the primary treatment units. All supernatant liquor from the digesters, together with the waste activated sludge, is pumped to the influent end of the primary units.

Dual Disposal Survey

In 1948 a consulting engineer was employed to make a survey of the situation with regard to enlarging the treatment works to care for the increased sewage flows and to include garbage treatment facilities. An order had already been received from the County Health Officer to stop the dumping of garbage on farm lands of the county. This order was issued about the last week of November, 1947, and was to become effective January 1, 1948. Action was delayed, however,

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pending action by the city to make provision for the disposal of garbage by some other means than by hog feeding.

The report recommended that the sewage treatment works be enlarged to handle a flow of 12 m.g.d. through all the units, and that sufficient digester capacity be added to permit digestion of garbage slurry with the primary and waste activated sludge. At the recommended rate of flow the primaries were enlarged to provide a detention time of 1.3 hr. with an overflow rate of 1,940 g.p.d. per square foot. The detention time in the aerators with a return of 30 per cent is 4.5 hr.; the detention time in the final units is 1.8 hr. with an overflow rate of 890 g.p.d. per square foot. The digester capacity was increased to 10 cu. ft. per capita on the basis of a population of 60,000 (39,000 in 1953).

Consideration was given several means of garbage disposal before it was decided that the best method for the city of Richmond was to treat the garbage with the sewage sludge, rather than by the use of land-fill or by incineration. It was known that some years previously tests had been made at Indianapolis to determine the possibility of treating the garbage with the sewage. Since that time other plants have attempted full-scale plant disposal of garbage, but with varying success if the annual plant reports could be relied upon. The investigation showed that the land-fill method was satisfactory if sufficient ground of proper composition and dryness was available at the right price, but no land of this nature could be found close enough to the city. Incineration was satisfactory if provision was made for smoke control, but the maintenance costs would be high and careful operation also would be necessary.

It was decided that disposal at the sewage treatment plant would work, but that the units should be designed accordingly. Another factor governing the selection of the grinding at the treatment plant was the fact that the plant personnel were familiar with the operation of grinding units. Also the gas generated by the treatment of the garbage had taken on added value, as the creation of a Sanitary District made any savings in power directly reflected in the tax rate. It was estimated that the amount of gas generated by the treatment of the garbage and the sewage would be sufficient to provide all of the return sludge pumping and most of the air needed in the activated sludge plant.

Basis of Garbage Unit and Digester Design

Data received from a similar operation at Marion, Ind., indicated that at least 10 cu. ft. of digester capacity per capita would be necessary, and that some means of grit removal was required before the garbage slurry was pumped into the digesters. All pipe lines handling garbage are flange connected so they can be removed easily for cleaning. Also all garbage pipes are laid in pipe chases or exposed. It also was decided that the maximum gas production could be derived from the direct introduction of the garbage slurry into the digester so that none of the volatile solids would be lost. Since the pumps that pump the garbage slurry into the digesters were to be used to pump sludge from the bottoms of the two new digesters it was decided that they should be of the plunger type. These same units can be used to transfer sludge from either of the new digesters to the other, or to pump sludge from the new units to the old units, or to circulate the sludge within the same digester. Experience at Marion also indicated the value of a picking area before the introduction of the garbage into the grinder for the removal of material that might injure the grinder or the grit washer. In the design of the Richmond plant an at-

tempt was made to avoid the troublesome things indicated by the operation of other plants and to incorporate as many of the desirable as possible.

Plant Expansion

The consultant's report was adopted and the plans and specifications were ordered prepared. Two things were constantly considered in all the design work. The first was that provision for additional sewage and garbage units must have a capacity for several years in the future. The second was that the time of necessary shutdown periods for connecting new and old units must be held to the absolute minimum to protect the river. It was anticipated that the connections would most likely be made when the river was at its most critical low stage.

The total cost of the plant expansions was $870,000, including legal fees, engineering fees, and bond costs. Of this amount approximately $101,750 could be attributed to the cost of the garbage equipment. On the basis of a design population of 60,000 this amounts to $1.69 per capita.

A completely new influent and effluent distribution system was constructed for the aeration units, including Parshall flumes for the primary effluent and for the effluent of each aeration plant.

Three new final settling tanks were constructed for the new aerators, and one for the excess flow of the old clarifiers, making a total of four new units. Telescoping valves were used to control the flow of return sludge from the final units. The return sludge is lifted 30 ft. to the effluent end of the Parshall flume. Either an electric-driven pump or a gas engine-driven pump may be used for return sludge pumping.

The aerators at the Richmond plant are one of its unique features. They are constructed on the side of a hill so that the flow enters the upper elevation of each unit and as it is discharged into the unit below pulls air in with the mixed liquor. Each aerator is made up of three units, each unit being 11 ft. 6 in. below the preceeding unit. Air dispersion is by swing type diffusers.

New Digesters

A material saving in the cost of the two 95-ft. diameter digesters was effected by the use of prestressed construction. Each of the new digesters is equipped with a floating cover and an external sludge heater. Several plant operators with experience in starting new digesters warned of the perils of "acid indigestion" when the units were started. One suggested that if one-third of the volume of the digester could be filled with digested sludge the unit would start out without any foaming or other trouble. Taking the warnings to heart, the old digestion units were allowed to become full to the brim with sludge so that there would be plenty to seed the new units at the proper time.

The new units were filled near the end of February to test the covers, and ground garbage was introduced. Then with dread the day of "acid indigestion" and foaming was awaited. Much to everyone's surprise nothing happened and the gas production was so low that the meters on the two new tanks had to be by-passed to prevent them from stopping up with condensate. Finally, in May, gas production began to increase and preparations were made to transfer the stored digested sludge into the new units, but there was no foaming. By June, gas production was really under way and in July a peak of 120,000 cu. ft. for a 24-hr. period was reached. There still was not the slightest indication of foaming, nor has there been any since. Now the problem is to get rid of the accumulation of stored digested sludge.

Garbage Handling

Garbage is collected in 1½-ton trucks equipped with covered beds and

brought to the sewage treatment plant. Each truck is weighed on a platform scale before the garbage is dumped into a hopper. A weigh slip is made out for each load so that an accurate account can be kept of the number of loads and the total weight of garbage for each day. An apron feeder removes a 24-in. depth of garbage from the hopper and discharges it onto a more rapidly moving apron, which in turn elevates the garbage and provides a uniform feed to a garbage grinder having a capacity of 3 tons per hour. Just before discharging to the grinder, a horizontal portion of the apron conveyor provides a picking table where the operator removes tin cans, large bones, and any other objectionable material that may have found its way into the garbage. The ground slurry from the ginder passes into a washer which removes the grit. In this case the grit is made up of small particles of egg shells, metal chips, bone chips, coffee grounds, and sand. The washed slurry discharges into a tank, from which a three-cylinder pump moves it directly into one of the new digesters. One pump is provided for each digester, but is so connected that either pump can be used to pump garbage slurry into either digester, or to transfer sludge from the bottom of one digester to the other, or to transfer sludge from the new units to the old digestion units, or to circulate the sludge from the bottom of one of the new units to the top of the same unit. Flexibility of operation with duplication of pumps insures continuous functioning of both of the primary digesters, even while heaters or pumps are being repaired.

Gas Utilization

As previously stated, one of the factors that made the grinding of garbage attractive was the expected gas production. To make full use of the gas, a new gas engine-driven blower unit having a capacity of 4,200 cu. ft. per minute with a 175-hp. engine, together with a new return sludge pump unit powered by a 65-hp. engine, was installed. Thus, there are two blower units powered by gas engines and one pump unit powered by a gas engine. The jacket water from the engines is used in the sludge heaters, furnishing most of the required heat. The sludge heaters also can be heated with gas or with fuel oil.

During 1952 the gas engine units furnished all of the air for the aeration units, except for 6 hr., and all of the return sludge pumping except for 8 hr. Gas was also used to heat the primary unit building and the office and laboratory building. The estimated value of the gas used was $1,500 for the colder months and $1,000 for the months when no building heat or extra heat for the digesters was required. A 32-ft. diameter gas sphere with a working pressure of 55 lb. per square inch was installed to insure more uniform operation of all gas burning equipment.

Sludge Disposal

Of the original four sludge drying beds, only one bed 50 ft. by 150 ft. remains. Practically all the digested sludge is disposed of in liquid form and hauled from the plant to farms by means of a 1,500-gal. tank truck belonging to the Sanitary District. A charge of $0.15 per mile is made for the total number of miles traveled. At present there is an ever-increasing demand for the sludge at all times of the year and the truck is operated during two shifts, or about 10 to 12 hr. per day.

Operation Problems

Several minor problems were encountered when the garbage grinding program was inaugurated. At first there was a tendency for the garbage in the hopper to arch over the feeding apron. Lifting fingers were installed on the feeding apron to tear the material loose. There also was a tendency for the material to bridge over at the

outlet door. Installation of a hand-operated screw inside the hopper immediately above the outlet allows the material in the hopper to be pushed down if necessary. More liquid was encountered in the garbage, even in dry weather, than had been anticipated. A diaphragm pump remedied this condition.

Data relative to the solids content in the garbage were found to be scarce, so some means of sampling the garbage loadings on the digesters was of importance. At first it was thought the best sample could be obtained from the slurry as it entered the slurry tank, but then it was found that there was no accurate way of determining the amount of slurry pumped to the digesters. Since the weight of the green garbage was known it was decided that a core from the garbage in the hopper, if properly secured, would give the best sample. This method was tried and a very satisfactory core could be taken, but then there was the problem of getting it in shape and suitable volume for laboratory tests. This situation was solved by the use of an ordinary kitchen-type hand-operated meat grinder. After the core was ground it was easy to get any portion desired for testing, as the ground mass was quite uniform. The standard methods for determining total solids and volatile solids are followed. Another difficulty that has as yet not been solved is the rapid deterioration of the evaporating dishes used in determining the volatile content. Three or four samples of garbage are tested each week.

To date there has been no noticeable difference in the amount of volatile solids from season to season. Neither has there been a large variation in the quantities of garbage collected from season to season. This lack of variation may well be due to the in-

TABLE I.—Performance of Primary Units Before and After Plant Additions

Year	Flow (m.g.d.)	Det. Period (hr.)	Suspended Solids			5-Day B.O.D.		
			Raw (p.p.m.)	Effl. (p.p.m.)	Rem. (%)	Raw (p.p.m.)	Effl. (p.p.m.)	Rem. (%)
(*a*) Original Plant								
1938	3.9	2.1	236	74	68.8	136	88	35.3
1939	4.3	2.0	188	80	57.4	130	101	22.3
1940	4.4	1.9	194	86	55.5	134	96	28.4
1941	4.5	1.9	228	91	60.2	160	116	27.5
1942	5.1	1.6	217	105	51.7	154	121	21.4
1943	5.0	1.7	213	98	54.2	147	127	13.6
1944	5.6	1.5	170	91	46.5	136	106	22.1
1945	5.7	1.5	164	85	48.2	119	99	16.8
1946	5.8	1.4	133	82	38.9	132	112	15.1
1947	5.8	1.4	139	112	19.4	125	108	13.6
1948	5.1	1.7	165	96	41.8	98	75	23.5
1949	5.9	1.4	142	99	30.3	121	101	16.5
1950	6.6	1.3	143	133	7.0	117	115	0.0
Av.	5.2	1.7	179	95	46.8	131	105	19.8
(*b*) After Plant Additions								
1951*	6.0	2.6	143	79	44.7	113	79	30.2
1952	7.0	2.3	132	69	47.8	95	68	28.5
Av.	6.5	2.5	138	74	46.4	104	73	29.9

* Based on July through December.

TABLE II.—Activated Sludge Plant Data

Year	Aer. Per. (hr.)	Air Supplied (cu. ft./gal. sew.)	Mixed Liquor Susp. Solids (p.p.m.)	Sludge Index	B.O.D. Rem. (lb./1,000 cu. ft. air)
			(*a*) Original Plant		
1938	7.8	0.74	2,250	106	0.72
1939	7.4	0.71	1,685	76	0.86
1940	7.4	0.69	1,636	120	0.86
1941	7.0	0.80	1,720	178	1.21
1942	6.5	0.44	1,500	112	1.94
1943	6.7	0.39	1,521	79	2.34
1944	6.2	0.49	1,585	101	1.40
1945	6.7	0.38	1,540	85	2.09
1946	6.7	0.34	1,820	90	2.40
1947	6.8	0.35	1,846	101	2.13
1948	6.9	0.39	1,590	117	1.10
1949	6.4	0.44	2,082	95	1.64
1950	5.2	0.44	3,130	63	1.62
Av.	6.4	0.50	1,840	102	1.62
			(*b*) After Plant Additions		
1951*	9.5	0.64	2,230	83	1.12
1952	7.6	0.55	2,310	76	0.97
Av.	8.6	0.60	2,270	80	1.05

* Based on July through December.

creased use of frozen and specially processed foods that have to a large extent replaced the home preparation of many foods.

One operator does all the grinding, weighing, greasing, and cleaning up of the equipment, as well as some of the light maintenance work. There have been occasions when it was necessary to have a second operator help to keep the garbage feeding through the gate of the hopper, but these times have been so few and for such short periods that they have not been considered.

Experience has also shown the importance of ample ventilation in the grinding room and around all the equipment that comes in contact with the garbage. A large volume of clean water for washing is also essential where the grinding is done in an enclosure. A search is still on at the Richmond plant to find some way of keeping maggots in check, as they constitute a real problem during the hot summer months.

Operating Results

As far as the Richmond Sanitary District is concerned, the garbage problem, from the standpoint of both collection and disposal, has been solved in a most satisfactory manner. The present method is economical and is really a satisfactory method as far as the health standpoint is concerned.

Several tables have been worked out to show the relation of the operation of the various treatment plant units before and after garbage disposal was made a part of the plant operations. It was found that in some cases there was more effect from other sources than the garbage, especially in the units which were badly overloaded before the additions were completed. In no instance has there been evidence of a failure of any unit due to the addition of the ground garbage. Table I shows

TABLE III.—Performance of Final Clarifiers

Year	Flow (m.g.d.)	Det. Period (hr.)	Suspended Solids			5-Day B.O.D.		
			Infl. (p.p.m.)	Effl. (p.p.m.)	Rem. (%)	Infl. (p.p.m.)	Effl. (p.p.m.)	Rem. (%)
(*a*) Original Plant								
1938	3.9	3.1	74	12	84.0	88	6	93.0
1939	4.3	2.8	80	14	82.5	101	6	94.0
1940	4.4	2.7	86	20	76.9	96	9	90.8
1941	4.5	2.6	91	13	85.9	116	5	95.8
1942	5.1	2.3	105	11	89.5	121	5	95.6
1943	5.0	2.4	98	21	78.5	127	8	93.5
1944	5.6	2.1	91	16	82.6	106	6	94.5
1945	5.7	2.1	85	17	80.3	99	5	95.0
1946	5.8	2.0	82	17	79.3	112	5	95.4
1947	5.8	2.0	112	16	85.7	108	6	94.6
1948	5.1	2.3	96	33	65.8	75	12	84.0
1949	5.9	2.0	99	17	82.8	101	14	86.0
1950	6.6	1.8	133	31	76.8	117	19	83.7
Av.	5.2	2.3	96	18	81.2	105	8	92.5
(*b*) After Plant Additions								
1951*	6.0	4.6	79	17	78.5	79	9	88.6
1952	7.0	4.0	69	10	85.6	68	6	91.3
Av.	6.5	4.3	74	14	81.0	74	8	89.1

* Based on July through December.

the performance of the primary settling units. As pointed out earlier, no metering facilities were provided to measure the excess primary effluent that could not be handled by the activated sludge plant. From 1947 to 1951 the amount of sewage given primary treatment only increased to about 2.0 m.g.d. Therefore, the removals shown in Table I from 1947 to 1951 show decreasing removals of solids and B.O.D. and by 1950, practically no solids or B.O.D. were removed by the primary units. Removals in 1951 and 1952 are about normal and certainly show no deterioration since the introduction of garbage digestion.

TABLE IV.—Garbage Data, 1952

Month	Collection		Solids	
	Per Month (1,000 lb.)	Per Day (lb./cap.)	Total (%)	Vol. (%)
Jan.	436.9	0.36	21.2	94.0
Feb.	296.7	0.26	21.2	94.0
Mar.	321.6	0.27	21.2	94.0
Apr.	339.6	0.29	21.2	94.0
May	337.8	0.28	21.2	94.0
June	411.8	0.35	20.2	93.0
July	477.8	0.40	22.3	95.3
Aug.	471.9	0.39	26.7	94.6
Sept.	492.3	0.42	24.5	94.0
Oct.	385.0	0.31	26.9	95.1
Nov.	316.9	0.27	24.8	95.5
Dec.	410.9	0.34	25.2	95.8
Av.	414.0	0.35	24.4	94.7

Table II shows the performance of the activated sludge plant before and after the additions were completed. It should be pointed out that the amount of air supplied the aerators was far in excess of that actually required, but the blower unit was operated at its lowest speed so the air was used. In 1951 and 1952 the sludge was in much better condition and there was never any trouble from bulking.

Table III gives performance data for the final clarifier units before and after the plant expansion program. From the standpoint of solids and

B.O.D. removals the extended plant shows considerably better removals and there were no periods of primary effluent by-pass such as occurred prior to 1951.

Table IV gives the garbage weights and solids contents for 1952, the first year when complete records were available. The amount of garbage per capita per day is somewhat lower than was assumed and there were not the seasonal variations generally reported.

Table V gives the digester performance data, which are very interesting. Through 1945, quite satisfactory operation was obtained, as evidenced by the gas production, the quality of the sludge withdrawn, and the destruction of volatile solids. From 1945 on, the operation of the digesters went from bad to worse, until by 1950 only 3.0 cu. ft. of gas was produced per pound of volatile solids added. The removal of volatile solids had dropped to 17.5 per cent and the supernatant was about like the raw sludge being added to the digesters. The loading of the digesters, in pounds of solids per cubic foot of digester capacity per month, shows wide variations with very heavy loadings in 1949 and 1950. The picture in 1951 and 1952 was quite different. The average gas production for 1951–52 was 232 per cent above that for the original plant. The gas per pound of volatile solids added was approximately as high as for the best year shown in the original plant. The amount of volatile solids digested indicates good digestion and shows no slowing up due to the addition of the garbage. The solids loading is the sufficient capacity.
lowest on record and is evidence of

Table VI gives the financial picture on garbage grinding and treatment at the sewage treatment works. The costs are based on one man's time for 8 hr. per day, although only about 3 hr. are actually spent in grinding. The cost

TABLE V.—Digester Performance Data

	11-Yr. Av.	1949	1950	1951*	1952
Raw sludge:					
Solids (%)	3.35	2.57	3.34	2.34	3.32
Volatiles (%)	64.0	61.5	56.5	61.6	59.3
Dry solids (1,000 lb./mo.)	252	296	498	404	421
Vol. solids (1,000 lb./mo.)	158	182	282	249	250
Garbage:					
Green (1,000 lb./mo.)	—	—	—	530	414
Dry solids (1,000 lb./mo.)	—	—	—	124	101
Vol. solids (1,000 lb./mo.)	—	—	—	117	96
Solids (%)	—	—	—	23.4	24.4
Volatiles (%)	—	—	—	94.2	94.7
Combined sewage and garbage:					
Dry solids (1,000 lb./mo.)	—	—	—	528	522
Volatiles (1,000 lb./mo.)	—	—	—	366	346
Digested sludge removed:					
Solids (%)	7.42	5.10	—	—	7.61
Volatiles (%)	49.6	52.9	—	—	50.2
Vol. digested (%)	36.1	29.3	17.5	48.5	49.3
Digester loading:					
Lb. sol./cu. ft./mo.	1.72	2.03	3.42	0.89	0.88
Lb. vol. sol./cu. ft./mo.	1.09	1.25	1.93	0.61	0.58
Gas production:					
1,000 cu. ft./month	854.9	823.3	761.0	2,730.0	2,837.2
Cu. ft./lb. volatiles	6.2	4.6	3.0	7.3	8.2
Garbage (tons/m.g.d. sewage)	—	—	—	1.5	1.0

* July through December.

TABLE VI.—Garbage Disposal Costs

Costs:	
Grinder and conveyor operation, including labor (2,474 tons @ $1.06)	$2,620
Pumping garbage slurry to digesters (4,000 kw.-hr. @ $0.0125)	50
Supervision	500
Maintenance	250
Hauling liquid sludge (353 loads @ $1.75)	620
Total Operating Cost	$4,040
Credits:	
Garbage gas (8,080,000 cu. ft. @ $0.65 per 1,000)	$5,250
Sludge (353 loads @ $1.50)	530
Total credit	$5,780

Net profit
($5,780 − $4,040/2,474 tons) = $0.70 per ton.

of power was for the grinder, washer, conveyor drive, and pump. The cost of hauling sludge was based on the assumption that the number of loads chargeable to garbage is in direct proportion to the percentage of dry garbage solids to total dry solids added to the digesters. Since garbage solids are 95 per cent volatile and the sewage solids are 60 per cent volatile, certainly this method of figuring is on the conservative side. On the credit side, the value of the garbage gas is figured at the current rate for gas supplied by the local gas company. If the gas was wasted the cost of disposing of the garbage by this method would be $1.64 per ton. By using the gas in the engines, thereby reducing the cost of power that would have to be paid for, the Richmond installation shows an actual operating profit of about $0.70 per ton of garbage.

Conclusions

The results of nearly two years of operating experience once more show that ground garbage can be satisfactorily digested with sewage solids at the sewage treatment works. It is pointed out, however, that the plant facilities should be adequate for the added garbage load. In addition, primary and secondary treatment units function as efficiently as before garbage was handled at the plant. Furthermore, this method is attractive financially when the gas produced can be used to reduce power costs. Digester capacity of 10 cu. ft. per capita for digestion of garbage, primary sludge, and excess activated sludge solids should be sufficient, but not much less than that volume should be provided.

FELLOWSHIPS AVAILABLE AT RUTGERS

Announcement has been made that applications for a newly established Dorr Company graduate fellowship in the Department of Sanitation at Rutgers University for the year 1954–5 will be received until April 1, 1954. The appointment, to be made about April 15, 1954, will be on a 12-month basis beginning September 1, 1954. A stipend of $1,800 per year plus tuition has been made available.

The fellowship is open to citizens of the United States or Canada holding B.S. or M.S. degrees in chemistry, biochemistry, biology, bacteriology, civil engineering, sanitary engineering, or chemical engineering.

In addition, a number of other fellowships are available for applicants having the same qualifications.

Application forms and further details may be obtained from: Dr. Harold E. Orford, Department of Sanitation. Rutgers University, New Brunswick, N. J.

RESEARCH ON ACTIVATED SLUDGE

IV. Purification with Intense Aeration

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The purification capacity of an activated sludge plant is closely related to the rate of oxygenation. Having acquired this insight, Kessener and Ribbius (1)(2)(3) advanced the concept of "oxygenation capacity" (O.C.), which value is understood to mean the rate of oxygenation in (distilled) water at a temperature of 10° C. and a barometric pressure of 760 mm. for an oxygen content of 0 p.p.m.

The oxygenation capacity of an aeration plant may be expressed in grams per hour per cubic meter and is determinable in a simple manner (4). The determination of this value is essential for judging the capacity and efficiency of an aeration plant.

Since Kessener and Ribbius, only a few experimenters have proceeded to measure oxygenation capacities. Edmondson and Goodrich (5) succeeded in increasing the oxygenation capacity of a Haworth plant by about 100 per cent and the efficiency by 50 per cent by making use of O.C. determinations. Improvements in aeration by the rotating brush system also proved possible of achievement with the aid of O.C. determinations (4).

In 1948 Pomeroy (6), who was not acquainted with the publications of Kessener and Ribbius, likewise drew attention to the importance of determining the oxygenation capacity and efficiency. By a method of determination similar to that employed by Kessener and Ribbius, the O.C. in a certain plant was in this case found to have a value of about 5 g. per hr. per cu. m. (=oz. per hr. per 1,000 cu. ft.), which value it proved possible to increase to about 20 g. per hr. per cu. m. by a different system of operation, while the amount of oxygen introduced into the water per kilowatt was increased fivefold.

These recent experiments again show how important the determination of the oxygenation capacity is in the practice of activated sludge purification. This consideration carries all the more weight as it has been found by experience that the improvement of oxygenation in an existing plant results in an increase in the purification capacity of the plant. The improvements found in the Haworth aeration system were turned to account by Edmondson and Goodrich in a purification plant, and it was found that in this way 60 per cent more sewage could be treated.

Limit of Oxygenation Capacity

An important problem still awaiting solution is: How far is it possible to go in this direction—or, in other words, to what extent is the oxygenation capacity the limiting factor that determines the purification capacity of a plant? Should it prove possible by efficient means to double or further multiply the oxygenation capacity in an aeration plant and should it be found that the purification capacity of the plant can be increased in proportion, a much smaller tank volume would serve the purpose and in this way a great saving in construction costs would be effected.

FIGURE 1.—Experimental brush aeration tank, showing turbulence developed, special baffle in place (left), and special baffle removed (background).

In a previous paper (7) it was shown that theoretically the rate of oxygen supply to the floc decreases as the floc size becomes larger and the degree of turbulence is lowered. Theoretical considerations show that the rate of biochemical oxidation can be increased by reducing the size of the floc and increasing the degree of turbulence in the liquid.

Part II of this series (4) reported on experiments with the brush aeration system, in which a high degree of turbulence was maintained in the water by aerating with the brush in a small tank. In this small tank the necessary conditions are realized to permit of ascertaining whether, at very high rates of oxygenation, the rate of oxygen consumption also is much higher.

Independently of the theortical considerations set forth in the previous paper (7), one may reason as follows:

In present-day practice good results are being obtained in an aeration tank with an O.C. of 50 g. per hr. per cu. m. and 12 per cent floc volume after 1-hr. sedimentation.

It may be anticipated that in a tank with an O.C. of 300 g. per hr. per cu. m. and 72 per cent floc volume, six times the amount of organic matter will be oxidized per cubic meter. This simple thesis would seem on theoretical grounds to be unassailable.

Experimental Plant

The experiments were conducted in a small treatment plant using activated sludge with brush aeration. The plant, which handles the sewage of a sanatorium, comprises an Imhoff tank, an aeration tank, a secondary sedimentation tank, and a digester.

The aeration tank, which has a capacity of 8 cu. m. (282 cu. ft.), is fitted inside with a rotating brush 4 m. (13.1 ft.) long and 42 cm. (16.5 in.) in diameter and having a rotational speed of 114 r.p.m. The brush is partly surrounded by a hood. Particulars of the

aeration tank and brush are given in a previous paper (4) (also see Figure 1).

Operation Methods

A treatment plant in which the activated sludge process is employed can be operated in different ways, as follows:

1. From the outset the total amount of sewage can be passed through the plant, applying vigorous aeration, and leaving it to circumstances to bring about the necessary flocculation. In the case of new plants, which as a rule are not overloaded, this procedure generally gives the desired result, which is complete treatment of the sewage.

2. An alternative method is to begin by developing a good quality of floc with small amounts of sewage, for which purpose one may, if desired, start with floc from an existing plant. The floc is carefully developed to a larger quantity, due precautions being taken to ensure that it maintains its good properties.

First Test Run

Although conditions in the plant with the small aeration tank are altogether different from those in a standard plant as used in practice, it was nevertheless decided to see first of all what result would be obtained by the first of the foregoing methods of operation.

At the beginning of October, 1948, the plant was put into service, with the entire sewage flow being passed through the plant. Samples were taken from time to time of the final effluent and the contents of the aeration tank.

The brush was immersed to a depth of between 7 and 8 cm. The rate of return of the sludge was 24 cu. m. per hr. The load was 140 cu. m. per day with 274 g. B.O.D. per cu. m., making a total of 38,360 g. B.O.D. per 24 hr., which is equivalent to 4,800 g. B.O.D. per 24 hr. per cu. m. of aeration tank volume (300 lb. per 1,000 cu. ft. per 24 hr.). This is six to eight times the load usually encountered in

TABLE I.—Results of First Test Run; Loading 4,800 Grams B.O.D. per Cubic Meter of Aeration Tank Volume per 24 Hours*

Date	Secondary Effluent							Mixed Liquor		
								Susp. Solids		
	pH	NH_4^+ (p.p.m.)	NO_2^- (p.p.m.)	NO_3^- (p.p.m.)	$KMnO_4$ (p.p.m.)	B.O.D. (p.p.m.)	Meth. Blue Stab. (hr.)	(ml./l./hr.)	(mg./l.)	(ml./g.)
1948										
Oct. 7	7.1	55	—	—	51	>70	8	—	—	—
Nov. 11	7.1	54	Trace	—	30	24	<23	—	—	—
Dec. 3	7.4	50.6	—	—	37	32	22	540	5,232	103
Dec. 7	7.2	45.7	—	—	35	27	<22	—	—	—
Dec. 17	7.9	44.8	—	—	36	37	18	—	—	—
Dec. 29	7.6	45.7	Trace	—	47	35	3.5	860	5,764	149
1949										
Jan. 4	7.8	82.9	—	—	—	108†	6	980	7,240	135
Jan. 10	7.8	62.6	Trace	—	32	50	<21	970	9,400	103
Jan. 13	7.8	57.1	Trace	—	32	19	54	910	11,080	82
Jan. 15	7.6	63.5	Trace	—	30	16	<18	910	7,188	127
Aver.‡	7.58	56.3	—	—	35	39	—	—	—	—

* Equivalent to 300 lb. B.O.D. per 1,000 cu. ft. per 24 hr.
† After stoppage of plant.
‡ Average from Nov. 11, 1948 to Jan. 15, 1949.

practice. The results of the experiment are given in Table I.

For this initial trial, the results obtained with a very high load cannot be considered bad. Viewed in retrospect, there were two circumstances which had an adverse effect.

The first was that the depth of immersion (7 to 8 cm.) was obviously too small. This was largely due to the fact that it was not realized at the time that the load was actually much greater than had been anticipated, having a population equivalent of about 1,100 instead of 800 as intended. Consequently, the sludge had a dark, almost black appearance, whereas in the later periods, when the floc was rich in oxygen, the sludge was of a fine brown color.

The second factor was that during the test period a high sludge content was maintained in the aeration tank. The resulting floc blanket formed in the secondary sedimentation tank consumed oxygen, thus having an adverse effect on the treated water ascending through it. Moreover, it was subsequently found that better results could be obtained by working with a lower suspended solids content in the aeration tank.

The experiment described was terminated in January, 1949, because of work to be done in the plant.

Second Test Run

When putting the plant into service again it was decided to start with a good quality of floc from a neighboring plant and to let the floc develop gradually to a larger amount. This trial proved a failure. The temperature was between 7° and 9° C. At this low temperature the nitrification process begins slowly or not at all. When, at the beginning of April, there were found to be many threads in the floc, it was decided to start afresh with a good quality of floc.

This time the nitrification process started up quickly (the temperature was about 13° C.). As the floc developed in the plant the supply of sewage was increased. The progress of the second test run is recorded in Table II, which shows how, during the period of one month, the load was increased up to about 2,400 g. B.O.D. per cu. m. per 24 hr. (150 lb. per 1,000 cu. ft.).

It is evident from the data that this high load was easily handled. The effluent has a low B.O.D. and satisfies the methylene blue test. During the period from May 31 to June 16 the load was actually as high as 110 cu. m. of sewage per 24 hr., or about 3,800 g. B.O.D. per cu. m. of aeration tank capacity (235 lb. per 1,000 cu. ft.).

As increase of load entailed greater risk of failure of the experiment, it was considered expedient to run the plant for a fairly long period on a load of 70 cu. m. per 24 hr. The rate of supply of sewage was maintained, therefore, at 70 cu. m. per 24 hr. (that is, at about 50 percent of the total discharge of sewage from the sanatorium, or about 2,400 g. B.O.D. per cu. m. per 24 hr.).

In August, difficulties were experienced with the Imhoff tank. This resulted in large amounts of fermenting sludge passing from the primary settling unit into the aeration tank with the primary effluent. After a few weeks the state of the sludge was much changed. Although the effluent was still of the same good composition, the floc contained many threads (probably *Sphaerotilus*) and showed a poor index value.

Third Test Run

Powerful aeration and temporary diminution of the load did not result in a disappearance of the threads. The floc continued to be voluminous. On this account it was not possible to maintain more than 4 g. of matter in suspension per liter in the aeration tank. Larger quantities than this resulted in the formation of a floc blan-

TABLE II.—Results of Second Test Run

Date (1949)	Loading				Brush Immersion (cm.)		Return Sludge (cu.m./hr.)	Mixed Liquor					Secondary Effluent							
	Sewage (g.p.d.)*	B.O.D. (lb./1,000 cu.ft./24 hr.)	Sewage (cu.m./24 hr.)	B.O.D. (g./cu.m./24 hr.)	1st Part	2nd Part		Temp. (°C.)	Susp. Solids (ml./l./hr.)	Susp. Solids (g./l.)	Index	Ash in Solids (%)	pH	NH_4^+ (p.p.m.)	NO_2^- (p.p.m.)	NO_3^- (p.p.m.)	$KMnO_4$ 10 min. (p.p.m.)	B.O.D. (p.p.m.)	Meth. Blue Stab. (hr.)	Appearance
Apr. 13	2,642	21	10	340	3	3	—	13	134†	1.262	106	17.6	—	—	—	—	—	—	—	—
Apr. 20	3,963	32	15	510	—	—	8	12	250	1.800	139	16.1	7.8	33.3	1.3	21.1	20	9	>96	Clear
Apr. 26	5,284	42	20	680	—	—	8	—	350	2.346	149	14.5	7.7	36.9	1.5	8.9	23	19	>96	Clear
Apr. 27	—	—	—	—	—	—	8	—	375	2.674	140	13.6	7.7	41.0	1.2	15.0	27	17	>96	Clear
May 3	7,926	64	30	1,025	6	6	8	13	580	3.416	170	14.6	7.4	35.7	4.5	20.0	27	21	>96	Clear
May 4	—	—	—	—	—	—	—	—	550	3.488	158	18.3	—	—	—	—	—	—	—	—
May 6	9,247	75	35	1,200	—	—	8	13	670	3.520	190	15.2	7.8	34.7	8.9	10.0	16	6	>96	Clear
May 10	11,889	97	45	1,550	—	—	8	14	760	5.344	142	13.3	7.6	37.1	5.6	—	22	10	>96	Clear
May 12	18,494	150	70	2,400	7	7	8	14	880	5.332	165	13.8	7.5	34.4	2.8	—	24	12	>96	Clear
May 13	—	—	—	—	—	—	8	14	750	5.640	133	13.2	7.0	34.4	2.6	—	25	15	>96	Clear
May 17	—	—	—	—	9	7	8	16	880	6.584	134	11.5	7.5	32.0	0.4	8.0	26	7	>96	Clear
May 24	—	—	—	—	—	—	8	16	935	7.664	122	13.1	7.1	26.4	1.1	—	29	32	<71	Clear‡
May 25	—	—	—	—	—	—	24	16	—	—	—	—	7.5	26.4	1.0	—	23	34	<71	Clear‡
May 31	29,062	235	110	3,750	—	—	24	16	930	7.718	120	—	7.2	21.6	0.8	—	23	43	>96	Sl. opaque‡
June 6	—	—	—	—	11	9	24	—	750	7.472	104	10.7	—	—	—	—	—	—	—	—
June 9	—	—	—	—	—	—	24	17	900	6.784	133	12.1	7.4	30.6	0.9	—	34	19	<43	Sl. op.
June 16	18,494	150	70	2,400	10	8	24	—	—	—	—	—	7.3	35.1	1.5	Trace	23	13	>96	Clear§
June 24	—	—	—	—	—	—	24	—	730	6.348	115	13.5	7.4	16.9	2.6	—	25	20	>96	Clear**
July 1	—	—	—	—	—	—	24	—	375	1.708	220	16.2	7.2	15.9	11.8	Trace	23	11	>96	Clear
July 4	—	—	—	—	8	6	24	—	460	4.834	95	13.2	7.1	22.3	2.4	—	26	10	>96	Clear
July 8	—	—	—	—	5	5	24	—	700	7.128	98	11.2	7.3	19.5	2.0	—	23	13	>96	Clear††
July 15	—	—	—	—	—	—	24	—	540	4.908	110	13.4	6.9	18.3	1.7	5.6	22	14	>96	Clear††
July 25	—	—	—	—	—	—	24	—	600	5.816	103	—	6.6	17.4	3.1	—	25	14	>96	Clear††
Sept. 1	—	—	—	—	—	—	24	—	700	3.678	190	12.9	7.2	24.7	0.7	—	22	23	>96	Clear

* U.S. gallons.
† New sludge from Tilburg plant.
‡ Sludge blanket in secondary settling tank.
§ Thin sludge blanket.
** Too much sludge removed.
†† Effluent particularly good, crystal clear.

TABLE III.—Results of Third Test Run*

Date (1949)	Primary Effluent										Secondary Effluent							
	Daily Flow (cu.m.)	Solids (ml./l./hr.)	pH	Prot. NH_4 (p.p.m.)	NH_4^+ (p.p.m.)	Cl^- (p.p.m.)	$KMnO_4$ (p.p.m.)	B.O.D. (p.p.m.)	B.O.D. (g./24 hr.)	Pop. Equiv.	pH	NH_4^+ (p.p.m.)	NO_2^- (p.p.m.)	NO_2^- (p.p.m.)	Cl^- (p.p.m.)	$KMnO_4$ (p.p.m.)	B.O.D. (p.p.m.)	Meth. Blue Stab. (hr.)
Oct. 19	69	0.4	7.2	8.7	50.5	56	104	235	16.215	464	7.5	21.1	3.0	Nil	63	23	4	>96
Oct. 20	69	—	7.1	10.1	58.8	60	120	270	18.630	532	7.6	26.2	2.77	Nil	70	33	11	>96
Oct. 21	68	0.5	7.2	8.3	62.4	63	122	264	17.952	513	7.4	35.8	1.42	Nil	70	35	9	>96
Oct. 22	53	0.1	7.2	9.2	68.9	70	128	294	15.582	445	7.4	42.2	1.75	Nil	74	37	12	>96
Oct. 23	54	0.1	7.3	9.2	72.5	70	130	294	15.876	454	7.5	50.5	0.91	Nil	74	42	10	>96
Oct. 24	59	1.5	6.8	13.8	65.3	70	152	308	18.172	519	6.8	51.4	1.85	Nil	77	40	12	>96
Oct. 25	74	—	6.8	10.1	56.9	56	117	214	15.836	452	6.8	42.2	0.95	Nil	70	32	9	>96
Oct. 26	69	—	6.9	10.1	63.2	56	136	300	20.700	591	7.5	42.1	0.44	Nil	70	35	13	>96
Oct. 27	87	0.4	7.1	9.6	55.9	49	135	270	23.490	671	7.6	39.4	0.33	Nil	70	37	12	>96
Oct. 28	70	Trace	7.0	10.1	58.6	60	123	276	19.320	552	7.5	39.4	0.25	Nil	70	34	12	>96
Oct. 29	66	0.2	7.1	9.2	64.1	63	136	270	17.820	509	7.5	42.2	0.33	Nil	70	36	11	>96
Oct. 30	70	0.7	6.9	8.2	67.8	58	132	249	17.430	498	7.4	47.6	1.40	Nil	65	36	12	>96
Aver.	67.3†	0.33	7.05	9.72	62.08	60.9	128	270	18.085	517	7.38	40.0	1.28	Nil	70.3	35	10.6	>96

* Average load, 2,350 g. B.O.D. per cu.m. aeration tank volume per 24 hr.; that is, 147 lb. B.O.D. per 1,000 cu.ft. aeration tank volume per 24 hr.
† 67.3 cu.m. = 17,780 gal. (U.S.).

ket. Although the floc did not, therefore, possess optimum qualities, it was decided to run a test in which the following points would be established as satisfactorily as possible:

1. The mean composition of the primary effluent fed to the tank.
2. The mean composition of the effluent.
3. The amount of sewage purified.

The results of this test are given in Table III, which shows that, with a loading of 2,350 g. B.O.D. per 24 hr. per cubic meter of aeration tank volume (= 147 lb. per 1,000 cu. ft. per 24 hr.), the water is fully purified, satisfies the methylene blue test, and has a mean B.O.D. not exceeding about 11 mg. per liter.

The depth of immersion was 6 cm. This corresponds to an oxygenation capacity of about 200 g. per hr. per cubic meter (= 200 oz. per hr. per 1,000 cu. ft.). The power consumption was 0.45 kw. per hour, corresponding to 0.8 w. per population equivalent.

Fourth Test Run

During a subsequent period the loading was increased to a mean value of about 3,150 g. B.O.D. per 24 hr. per cubic meter of aeration tank volume (Table IV). However, although 90 to 92 per cent of the B.O.D. of the primary effluent was eliminated in this test, the effluent no longer satisfied the methylene blue test.

Fifth Test Run

Some time later (1951) the Netherland Government Institute for Sewage Purification carried out further tests, in which a loading of 4,200 g. B.O.D. per 24 hr. per cu. m. of aeration tank volume (260 lb. per 1,000 cu. ft.) was applied. In this test the suspended solids content was maintained at a lower value than in the previous loading tests. The results are given in Table V.

From the values in Table V it follows that with a load of 4,200 g. B.O.D. per 24 hr. per cu. m. of aeration tank volume, the water is well-purified and loses its liability to putrefaction. The oxygenation capacity at a brush immersion depth of 13 cm. is about 400 g. per hr. per cu. m. The amount of returned sludge was 10.5 cu. m. per hr.

The time during which the sewage remained in the aeration tank averaged 1.5 hr. not counting return sludge, and 30 min. when return sludge was taken into account. (At peak hours these times are 40 min. and 22 min., respectively.)

The aerated sludge was light brown, had a good appearance under the microscope (granular, no threads, many living protozoa), and good settling qualities.

Discussion

The experiments described show that the purification capacity of an activated sludge plant is determined in the first place by the oxygenation capacity, as shown by Table VI.

Therefore, provided steps are taken to insure a sufficiently high oxygenation capacity, the volume of the aeration tank of an activated sludge plant may be made much smaller than was formerly required.

This is of importance not only for the building of new plants, but also in all cases where increased purification capacity is required. As a rule it will merely be necessary to increase the oxygenation capacity and the degree of turbulence (for example, by installing additional brushes in existing aeration tanks).

The results of the experiments conducted confirm the results of theoretical reasoning, which are to the effect that, by increasing the degree of turbulence and reducing the size of floc, it is possible with a high O.C. to improve the rate of supply of oxygen to the floc and to accelerate the process of biochemical oxidation. That in all

TABLE IV.—Results of Fourth Test Run*

Date (1949)	Primary Effluent										Secondary Effluent							
	Daily Flow (cu.m.)	Solids (ml./l./hr.)	pH	Prot. NH_4 (p.p.m.)	NH_4^+ (p.p.m.)	Cl^- (p.p.m.)	$KMnO_4$ (p.p.m.)	B.O.D. (p.p.m.)	B.O.D. (g./cu. m./ 24 hr.)	Pop. Equiv.	pH	NH_4^+ (p.p.m.)	NO_2^- (p.p.m.)	NO_3^- (p.p.m.)	Cl^- (p.p.m.)	$KMnO_4$ (p.p.m.)	B.O.D. (p.p.m.)	Meth. Blue Stab. (hr.)
Oct. 31	90	1.0	7.0	11.9	61.4	58.0	172	336	3,200	90	7.4	54.0	0.50	Nil	65	40	14	>96
Nov. 1	90	Trace	7.0	—	61.4	58.0	122	258	3,200	90	7.4	51.3	0.20	Nil	40	43	27	<66
Nov. 4	90	—	—	—	—	—	—	—	3,200	90	7.2	49.5	Trace	Nil	76	45	30	<42
Nov. 9	90	—	6.9	10.5	61.4	80.0	122	294	3,200	90	7.2	53.6	Trace	Nil	69	53	24	<21
Nov. 19	90	—	—	—	—	—	—	—	3,200	90	7.2	66.0	Trace	Nil	83	54	25	<47
Nov. 25	90	—	—	—	—	—	—	—	3,200	90	7.7	57.7	0.2	Nil	65	46	19	54
Nov. 26	90	0.7	7.2	16.0	90.2	87.0	173	368	3,200	90	7.7	68.7	Trace	Nil	91	44	20	<65
Nov. 27	90	Trace	7.1	13.7	102.6	87.0	171	392	3,200	90	7.8	77.4	Trace	Nil	98	65	26	<47
Nov. 28	90	0.8	7.2	13.7	87.4	72.0	184	400	3,200	90	7.8	32.1	Trace	Nil	98	67	23	76
Nov. 29	90	—	—	—	—	—	—	—	3,200	90	7.7	44.9	Trace	Nil	80	49	18	<47

* Average load, 3,150 g. B.O.D. per cu.m. aeration tank volume per 24 hr.; that is, 197 lb. B.O.D. per 1,000 cu.ft. aeration tank volume per 24 hr.
† 90 cu.m. = approx. 24,000 gal. (U.S.).

TABLE V.—Activated Sludge Loading Test "Klokkenberg 1951"*

Date (1951)	Primary Effluent			Mixed Liquor				Secondary Effluent							
	Daily Flow (cu.m.)	B.O.D. (p.p.m.)	B.O.D. Loading (g./cu.m./24 hr.)	Susp. Solids (ml./l./hr.)	Susp. Solids (g./l.)	Sludge Index (ml./g.)	Solids Ash (%)	pH	NO_2^- (p.p.m.)	NO_3^- (p.p.m.)	$KMnO_4$ (p.p.m.)	B.O.D. (p.p.m.)	Meth. Blue Stab. (hr.)	O_2 (p.p.m.)	Temp. (°C.)
Aug. 16	120	318	4,770	318	2.18	146	13.2	7.7	0.16	Nil	36	10	>96	0.6	—
Aug. 17	141	394	6,940	312	1.78	175	16.1	7.7	0.20	Nil	—	11	>96	1.6	—
Aug. 21	150	259	4,860	622	2.35	265	14.2	7.8	0.10	Nil	29	7	>96	0.9	25
Aug. 22	142	231	4,100	594	2.12	280	10.9	7.6	0.10	Nil	31	12	>96	0.9	19
Aug. 23	125	208	3,250	339	1.95	174	11.3	7.4	0.20	Nil	32	9	>96	1.6	20
Aug. 24	134	276	4,620	110	0.94	117	8.6	7.8	0.29	Nil	40	16	>96	0.9	22
Aug. 28	125	378	5,910	590	1.34	438	23.2	7.7	Nil	Nil	36	12	>81	0.5	18
Aug. 29	134	210	3,520	522	1.97	265	13.4	7.7	0.10	Nil	38	6	>96	0.6	20
Aug. 30	117	207	3,030	323	1.54	209	11.2	8.0	0.20	Nil	31	5	>96	1.3	24
Aver.	132	276	4,500	414	1.80	230	13.6	7.7	0.15	Nil	34	10	>94	1.0	21
Sept. 19	133	312	5,190	250	1.44	174	10.8	7.6	0.56	Nil	27	15	>96	1.8	16
Sept. 20	108	288	3,890	240	1.55	155	10.6	7.9	0.45	Nil	36	18	>96	0.9	16
Sept. 21	118	267	3,940	140	1.03	136	12.1	7.6	0.53	Nil	32	14	>96	1.6	15
Sept. 25	133	216	3,590	290	1.60	181	12.1	7.8	0.96	Nil	31	8	>96	1.8	15
Sept. 26	128	267	4,270	130	1.37	95	12.0	8.0	0.59	Nil	58	65	>62	1.1	16
Sept. 27	137	264	4,520	230	1.47	156	17.8	7.9	0.42	Nil	34	17	>90	0.8	15
Sept. 28	117	273	3,990	200	1.24	162	13.9	8.0	0.45	Nil	31	17	>96	1.6	16
Aver.	125	270	4,200	211	1.39	151	12.8	7.8	0.57	Nil	36	22	>90	1.4	16

* Experiment by Netherland Government Institute for Sewage Purification. Average load, 4,400 g. B.O.D. per cu.m. of aeration tank volume per 24 hr.; that is, 275 lb. B.O.D. per 1,000 cu.ft. of aeration tank volume per 24 hr.

TABLE VI.—Effect of Oxygenation Capacity on Purification Capacity of an Activated Sludge Plant

Plant	Oxygenation Capacity (g./cu. m./hr.)*	B.O.D. Loading	
		(g./cu. m./24 hr.)	(lb./1,000 cu. ft./24 hr.)
Normal practice	20 to 80	300 to 1,000	20 to 60
Klokkenberg, 1949	200	2,400	150
Klokkenberg, 1951	400	4,200	260

* Equivalent to ounces per 1,000 cu. ft. per hour.

probability the reduction of the size of floc is indeed an important factor is supported by the experience gained during the experiments of 1951, in which it was found that when operating with a load of 4,200 g. of B.O.D. per cubic meter of aeration tank volume good results were obtained with about the same sludge content in the aeration tank as is usual in plants presently in operation (approximately 1.5 g. per liter).

The results of tests being made in laboratory plants show that when aerating with compressed air it is possible to purify a similar amount, or even more, of B.O.D. per cubic meter per day. However, some caution must be observed in transposing the results obtained with brush aeration to those achievable with compressed air, the reasons for this being as follows:

1. The possibility of increasing the intensity of aeration in compressed air plants needs further investigation. Experiments on this point are in progress.

2. Even if it should prove possible to bring about a considerable increase of the oxygenation capacity per cubic meter of the aeration tank volume in compressed air plants, there may still be some difference in respect to turbulence as compared with a brush aeration plant. Turbulence may be less intense in the case of aeration by a compressed air system.

It should be noted that the reduction of the floc size by means of the rotating brush has no adverse effect on the properties of the sludge. During its passage from the aeration tank to the secondary sedimentation tank the floc coagulated rapidly to form larger sizes of floc. Also, when the brush is stopped for a brief period the surface of the liquid can be seen to "break" as a result of coagulation of the sludge.

Table VII gives the power consumption for aeration during the two trial periods in the Klokkenberg Sanatorium plant, those which have been taken as standard for the brush aeration project of the Netherland Government Institute for Sewage Purification, and the mean working results obtained with a

TABLE VII.—Power Consumption for Various Aeration Experiments

Plant	Aeration Intensity (w./cu. m.)*		Aeration Intensity (hp./1,000 cu. ft.)†		Loading (pop. eq./cu. m.)	Energy Expended (w./pop. eq.)	
	Net	Gross	Net	Gross		Net	Gross
Mogden, 1936–47	10	20	0.038	0.076	17	0.6	1.2
Brush aeration project	25	30	0.095	0.114	25	1.0	1.2
Klokkenberg, 1949	56	67	0.213	0.255	67	0.85	0.95
Klokkenberg, 1951	180	215	0.684	0.817	120	1.5	1.75

* Watts per cubic meter of aeration tank capacity.
† Horsepower per 1,000 cu. ft. of aeration tank capacity.

compressed air plant at Mogden, England.

It should be noted in this connection that during the 1949 test period at the Klokkenberg plant efforts were made to minimize power consumption, whereas during the 1951 test period excess aeration was applied.

These results indicate that purification with intensive aeration need not, or need only to a small extent, be accomplished by less efficient power consumption.

Conclusions

1. The purification capacity of an activated sludge plant is governed primarily by the oxygenation capacity.

2. By increasing the oxygenation capacity and the degree of turbulence it is possible to effect complete purification of much larger (6- to 8-fold) amounts of sewage per cubic meter of aeration tank volume than have formerly been considered possible.

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References

1. Jaarverslagen Rijksinstituut voor Zuivering van Afvalwater (Annual Reports, Netherland Govt. Inst. for Sewage Purif.) (1931, 1932, 1933).
2. Kessener, H. N. H., and Ribbius, F. J., "Comparison of Aeration Systems for the Activated Sludge Process." *Sewage Works Jour.*, **6**, 3, 423 (May, 1934).
3. Kessener, H. N. H., and Ribbius, F. J., "Practical Activated Sludge Research." *Proc. Inst. Sew. Purif.*, Part I, p. 50 (1935).
4. Pasveer, A., "Research on Activated Sludge. II. Experiments with Brush Aeration." THIS JOURNAL, **25**, 12, 1397 (Dec., 1953).
5. Edmondson, J. H., and Goodrich, S. R., "Experimental Work Leading to an Increased Efficiency in the Bioaeration Process of Sewage Purification." *Proc. Inst. Sew. Purif.*, Part II, p. 17 (1947).
6. Pomeroy, R., "Power Efficiency in Activated Sludge Aeration." *Sewage Works Jour.*, **20**, 2, 222 (Mar., 1948).
7. Pasveer, A., "Research on Activated Sludge. III. Distribution of Oxygen in Activated Sludge Floc." THIS JOURNAL, **26**, 1, 28 (Jan., 1954).

AN IMPROVED FORM OF THE MONOMOLECULAR FORMULA

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The rate of biochemical oxidation of organic matter has been observed to be proportional to the remaining concentration of unoxidized substance (1). This remaining concentration can be expressed as the difference between some ultimate oxidizable quantity, L, and the amount already oxidized, y, where both are measured in terms of the oxygen demand they represent. Thus, in a B.O.D. test y would be the amount of dissolved oxygen used at time t. The rate of biochemical oxidation can then be expressed as:

$$\frac{d(L-y)}{dt} = K(L-y) \qquad (1)$$

This is an equation of a first-order reaction which can be integrated between the limits of $y = y_0$ at $t = 0$, and $y = y$ at $t = t$, to give:

$$\frac{(L-y)}{(L-y_0)} = e^{-Kt} \qquad (2)$$

For many purposes the base 10 is preferred to the base e, or:

$$\frac{(L-y)}{(L-y_0)} = 10^{-kt} \qquad (3)$$

where the true reaction constant * $K = k/\log e = 2.3\,k$. Eq. 3 also can be written in the form:

$$y = L(1 - 10^{-kt}) + y_0 10^{-kt} \qquad (4)$$

It will be noted that if $y_0 = 0$, Eq. 4 reduces to the much-used form of the monomolecular equation

$$y = L(1 - 10^{-kt}) \qquad (5)$$

Orford and Ingram (3) found that the constants L and k of Eq. 5 depended on the number of days used in the calculation. It is of interest to determine what value of y_0 will give the best correlation of y and t for any particular case, and it is shown in the following that this is achieved when y_0 does not equal zero.

Differentiation of Eq. 4 with respect to t gives

$$\frac{dy}{dt} = k(L - y_0)(\ln 10)10^{-kt} \qquad (6)$$

or

$$\log (dy/dt) = \log [k(L-y_0)(\ln 10)] - kt \qquad (7)$$

Thus, a graph of log dy/dt *versus* t will be a straight line of slope $-k$. The intercept derived from the graph can be used to calculate $L - y_0$. The separate values of the constants are easily found by calculating $x = 10^{-kt}$ for the several values of t available then plotting y *vs.* x to find the constants in

$$y = L - (L - y_0)x \qquad (8)$$

A final check is easily made by using the derived value of L to calculate $L - y$ and plotting these values *versus* t on semi-logarithmic paper, using the relationship derived from Eq. 3,

$$\log (L - y) = \log (L - y_0) - kt \qquad (9)$$

It will be noted that in the method for finding k, no assumption is made

* The terminology of Phelps (2) is followed in this paper with K the true-rate constant and k the constant in the corresponding equation using logarithms to base 10.

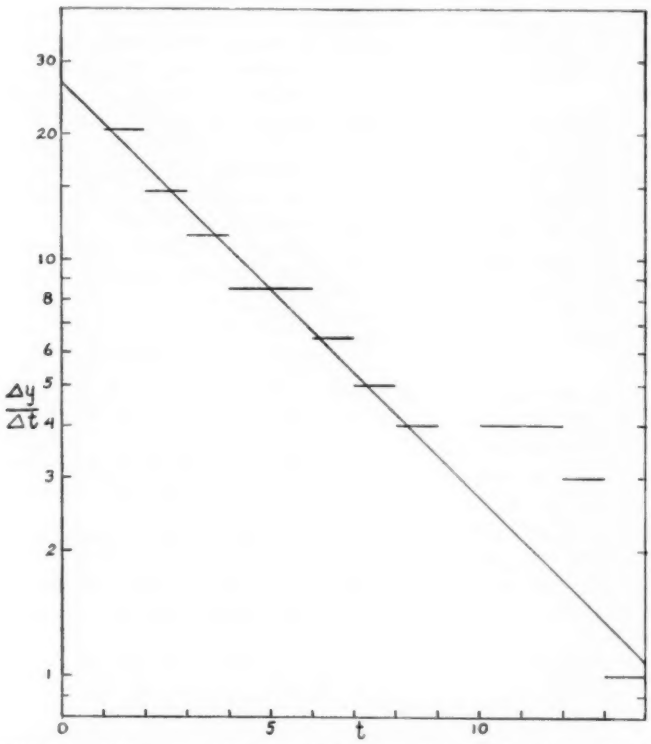

FIGURE 1.—Difference values for the determination of the rate constant, k.

TABLE I.—Calculation of Values for Graphs

Time, t (days)	B.O.D., y (p.p.m.)	$\frac{\Delta y}{\Delta t}$ (p.p.m./day)	$x = 10^{-0.1t}$	$138 - y$
1	45		0.795	93
		20.4		
2	65.4		0.631	72.6
		14.6		
3	80		0.502	58
		11.5		
4	91.5		0.398	46.5
		8.5		
5	100		0.316	38
		8.5		
6	108.5		0.251	29.5
		6.5		
7	114		0.200	24
		5		
8	119		0.158	19
		4		
9	123		0.126	15
		2		
10	125		0.100	13
		4		
11	129		0.079	9
		4		
12	133		0.063	5
		3		
13	136		0.050	2
		1		
14	137		0.040	1
		1		
16	139		0.025	−1
		0.5		
18	140		0.016	−2

about the value of y_0; the same is true of Eqs. 8 and 9. The value of y_0 is simply that which the data determine.

The data on measurements of oxygen demand in a B.O.D. test corrected for nitrification given by Orford and Ingram (4) serve to illustrate the method. Table I reproduces Orford and Ingram's values of y and t. In Column 3 of Table I are given the $\Delta y/\Delta t$ values, computed from the daily values; the resulting difference values are shown on semi-logarithmic paper in Figure 1. It can be seen in Figure 1 that the data begin to scatter widely and depart from linearity at about the ninth to the eleventh day. This is not surprising, as the differences are of the order of the precision of such values.

The value of $k = 0.10$ obtained from Figure 1 is then used to calculate $x = 10^{-kt} = 10^{-0.1t}$ in Column 4 of Table I, and the values of x are plotted against values of y in Figure 2. It

will be noted that the values diverge markedly from linearity at the twelfth day. From Figure 2, $L = 138$ and $y_0 = 23$.

Finally, Column 5 of Table I shows the calculation of $L - y$, or $138 - y$ in this case, and the resulting values are shown plotted on semi-logarithmic paper in Figure 3. The slope in Figure 3 is -0.1, agreeing with the previous determination of k; from the intercept, $y_0 = 25$, a close agreement with the earlier value of 23 from Figure 2.

It is not argued that y_0 has physical significance, but it is a value which appears to agree well with the data. It is a way of saying that at values of t greater than 0, the values of y behave as though y does not equal 0 at $t = 0$.

It might be noted that Phelps (2) uses the term L as the initial oxidizability at $t = 0$, and L_t as the value of L at time t. He further states that this is an abritrary choice for L and could represent any other time during the reaction. As such, he did not assign to L any concept of ultimate B.O.D. value.

It is evident that much more information can be gained if the B.O.D. test is run at two different times and with a smaller number of dilutions at each time. What one really desires to know is the value L, and its value cannot be determined from one time alone unless k and y_0 are known.

It is also of interest to note that Eq. 3 is quite similar to the form of equation used in conduction of heat in solid bodies, where the rate of temperature change is proportional to the remaining difference in temperatures.

Summary and Conclusions

A new form of the well-known monomolecular equation is presented—that

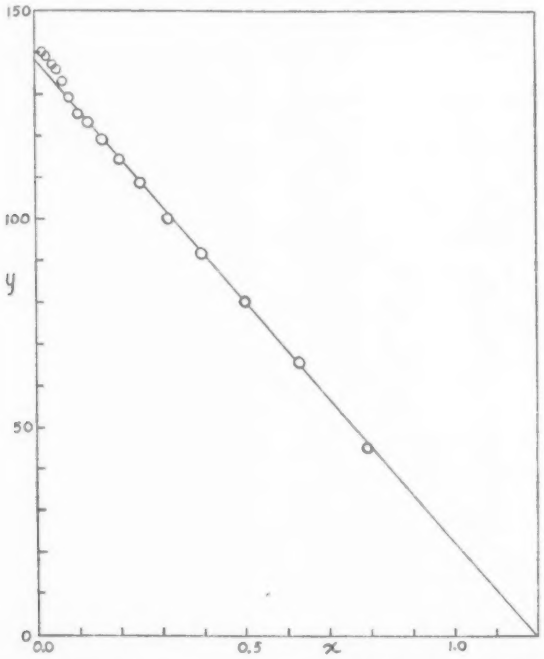

FIGURE 2.—Plot of $x = 10^{-0.1t}$ *vs.* y_t to determine constants in Eq. 8.

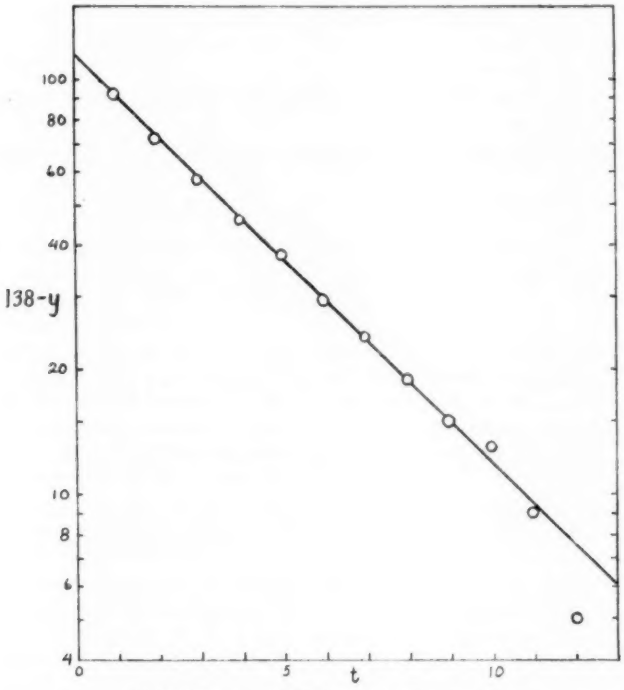

FIGURE 3.—Values of $138 - y_t$ *vs.* t.

is,

$$(L - y)/(L - y_0) = 10^{-kt}$$

—and it is shown how the constants k, L, and y_0 can be evaluated without simultaneous solution of equations. The equation is shown to agree well with carbonaceous B.O.D. data, and has the advantage that semi-logarithmic graphs give straight lines, allowing easy graphical treatment of the data. It is suggested that B.O.D. values at two different time periods will yield more basic data than a value at one time alone.

References

1. Streeter, H. W., and Phelps, E. B. Pub. Health Bull. 146, U. S. Pub. Health Service, Washington, D. C.
2. Phelps, E. B., "Stream Sanitation." Wiley & Sons, New York, N. Y. (1944).
3. Orford, H. E., and Ingram, W. T., "Deoxygenation of Sewage." THIS JOURNAL, **25**, 4, 419 (Apr., 1953).
4. Orford, H. E., and Ingram, W. T., "Deoxygenation of Sewage." Table I, Part II, THIS JOURNAL, **25**, 4, 427 (Apr., 1953).

BACTERIOLOGICAL STUDIES OF SLUDGE DIGESTION *

IV. A Motile Facultative Anaerobe Isolated from Digested Sludge

By T. C. Buck, Jr., C. E. Keefer, and Hester Hatch

Respectively, Assistant Director, Bureau of Laboratories, Baltimore City Health Department; and Deputy Sewerage Engineer and Senior Bacteriologist, Bureau of Sewers, Baltimore, Md.

This paper describes further investigations being made at the Back River sewage treatment works to isolate and study the various bacteria responsible for the digestion of sewage sludge. The organism reported on in this paper is a highly motile facultative anaerobic bacillus, growing singly and sometimes in chains. It was isolated from actively digesting sludge, which was drawn from one of the heated digesters at the Back River sewage treatment works, Baltimore, Md. This organism is of special significance for two reasons: (a) it resulted in the rapid production of gas when inoculated into raw sewage sludge, and (b) the motility of the cell contents was of great cytological interest.

Primary Isolation

Several series of plates, each plate containing 0.1 ml. of lactophenol solution (1) and sodium thyoglycolate in trypticase soy medium, were prepared. The plates were inoculated serially with diminishing quantities of digested sludge. After incubation for 24 hr. at 35° C. the fifth or sixth plate in the various series had well-defined colonies. The one containing the organism described in this paper was picked and a transfer was made to a series of plates containing the previously mentioned medium. By following this technique, one or more plates with discrete colonies were obtained. These colonies were cream-colored, 2 to 4 mm. in diameter, growing below the surface of the medium. They were circular when viewed from above and elliptical when viewed from the side. A cylindrical gas bubble had formed adjacent to each colony, the length of which was, in many instances, approximately 2½ times the diameter of the colony. In a number of instances the size of the bubbles varied with time. At 5 min. after the first observation, the length of the bubble had decreased approximately 50 per cent; 5 min. later it had increased to approximately its original size. The reduction in the size of the bubble may have been due to gas being absorbed by the medium.

Isolation for Pure Culture

These colonies were then picked with the aid of a Greenough microscope (30X). The agar covering the colony was removed with a very small scalpel to expose the colony. The colony was picked and a transfer was made to a number of conventional agar media, none of which contained lactophenol. The plates were then incubated at 35° C. in an atmosphere of carbon dioxide. This procedure was repeated at least 10 times to obtain the organism in pure culture. Three types of colonies developed. One was a large, light cream-colored, surface colony, 4 to 6 mm. in diameter. They were convex in elevation with entire edges. The internal texture of the colonies was

* Part III of this series appeared in This Journal, **25**, 12, 1406 (Dec., 1953).

finely granular. Small eliptical daughter colonies were frequently present inside the mother colony. The second type was a deep, transparent, colorless spreading colony, which had very pronounced slime-wall characteristics. Contrary to the usual observations of motile organisms, this colony was produced only upon the addition of lactophenol solution. The third type (Figure 1) was a deep pale yellow, spherical colony, 2 to 3 mm. in diameter, with a dark center and with filamentous edges of a typical medusa type and with veil-like interlacing. Each of the aforesaid colonies, when picked from agar, inoculated into broth, and replated on agar a number of times, reproduced each of the three colonies mentioned.

Morphology and Cytology

Each of the three types of colonies was picked, and the organism was Gram stained, Mallory spore stained, and examined in wet mounts. The Gram stain (Figure 2) revealed a highly pleomorphic Gram-positive bacillus, which grew singly and in chains and was 3 to 4 microns long by ½ to 1½ microns in diameter. There were also a great number of Gram-negative forms containing many Gram-positive bodies. Many oval, highly refractile bodies were observed in cultures 10 days old. Each body was approximately 3 microns long by 2 microns in diameter, the ectoplasm of which was stained Gram-positive with each end having a darker stain. No granules were observed in the central refractile area.

When Mallory's spore stain was used, these bodies contained a red ectoplasm with a pronounced red body at one end. Since the refractile areas absorbed the green dye, this organism probably produced spores.

When wet mounts were made from broth cultures 6 to 8 hr. old, a highly motile bacillus, singly and in chains, was observed. When aqueous methylene blue was added to the wet mount, spherical and elongated bodies were seen rapidly moving throughout the entire cell. Some cells contained none of these bodies, whereas other cells contained from 2 to 16. These bodies varied from 0.2 to 1.0 micron in diameter.

When wet mounts were heated to 45° C., and studied with a Leitz phase condenser at approximately 1,000 diameters, the endobodies were dark blue

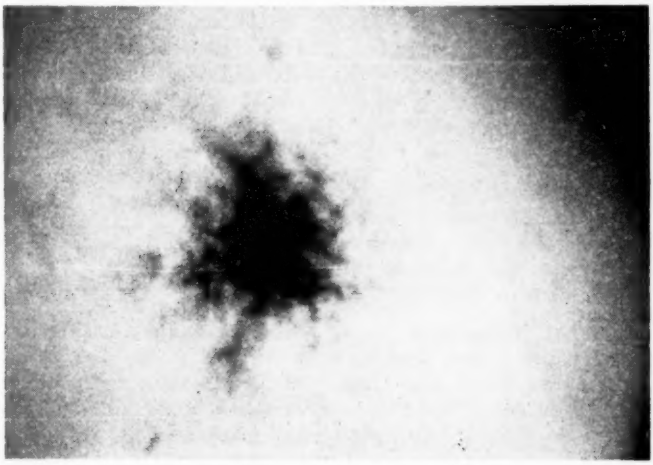

FIGURE 1.—Medusa-type colony.

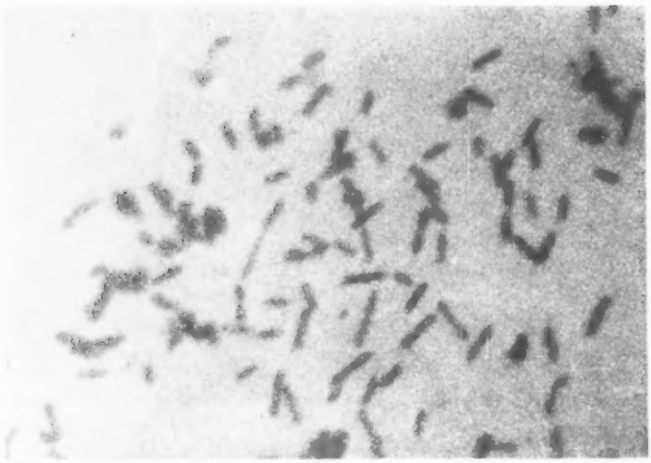

FIGURE 2.—*Bacillus endorhythmos* growing singly and in chains.

and very motile. Similar bodies, which were quite motile, were observed outside the cell. These bodies, which were both spherical and eliptical, were present as single cells and as aggregates. They may have been endospores. The presence of these motile endobodies was most unusual. Whether they escape from the mother cell into the surrounding medium and whether they are the same as the similarly shaped bodies in the menstrum, remain to be determined. Furthermore, the part that these endobodies play in the life process of the mother cell awaits further research.

Biochemical Reactions of the Organism

The organism was subjected to six series of 29 biochemical tests. The reactions (Table I), which were observed after 1, 2, 3, 10 and 20 days, revealed the following interesting facts:

1. Bile solubility tests were performed with a 0.5 per cent aqueous solution of Bacto ox bile. To equal parts of the solution, 5 ml. of a 24-hr. broth culture were added. No lysis occurred at the end of 1 hr. when incubated at 35° C. The organism, therefore, was considered not bile soluble.

2. Acid was formed without the production of gas in six of the carbohydrates tested.

3. Litmus milk became acid and coagulated in 24 hr. Within 48 hr. the dye had been reduced to its leuco base, and within 10 days liquefaction was observed in the lower half of the tube.

4. Blood agar was hemolyzed in 24 hr. with an outer zone, indicating methemoglobin.

5. Gelatin was rapidly liquefied in 24 hr. Liquefaction was complete in 3 days in deep stab cultures.

6. The IMVIC tests were performed according to "Standard Methods" (2). The organism was methyl-red positive, Voges-Proskauer negative, and citrate negative. No growth was obtained in peptone broth when the indol test was made.

7. Catalase tests were positive within 24 hr.

8. Urease gave a positive test within 24 hr.

9. Triple-sugar-iron medium heavily inoculated in the butt and also on the slant gave a good growth within 3 days, but without the production of hydrogen sulfide or gas.

TABLE I.—Biochemical Reactions of *Bacillus endorhythmos*

Medium	1 Day			2 Days			3 Days			10 Days			20 Days		
	Growth	Acid	Gas	Growth	Acid	Gas	Growth	Acid	Gas	Growth	Acid	Gas	Growth	Acid	Gas
Arabinose	++	Neg.	Neg.	++	Neg.	Neg.	++++	Neg.	Neg.	++++	Neg.	Neg.	++++	Neg.	Neg.
Bile solubility	Neg.	—	—	Neg.	—	—	Neg.	—	—	Neg.	—	—	Neg.	—	—
Blood agar	+[1]	—	—	+[1]	—	—	—	—	—	—	—	—	—	—	—
Catalese	Pos.	—	—	Pos.	—	—	—	—	—	—	—	—	—	—	—
Cellulose	Neg.	—	—	Neg.	—	—	Neg.	—	—	Neg.	—	—	Neg.	—	—
Citrate	Neg.	—	—	Neg.	—	—	Neg.	—	—	Neg.	—	—	Neg	—	—
Dextrose	+	Ac.	Neg.	+	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.
Dulcitol	++	Neg.	Neg.	++	Neg.	Neg.	++++	Neg.	Neg.	++++	Neg.	Neg.	++++	Neg.	Neg.
Galactose	++	Sl. Ac.	Neg.	++	Sl. Ac.	Neg.	++++	Sl. Ac.	Neg.	++++	Sl. Ac.	Neg.	++++	Sl. Ac.	Neg.
Gelatin	+[2]	—	—	+[2]	—	—	+[2]	—	—	+[2]	—	—	+[2]	—	—
Hydrogen sulfide	Neg.	—	—	Neg.	—	—	Neg.	—	—	Neg.	—	—	Neg.	—	—
Indol	++	Neg.	—	++	Neg.	—	+++	Neg.	—	++++	Neg.	—	++++	Neg.	—
Inositol	+	Neg.	Neg.	+	Neg.	Neg.	++++	Neg.	Neg.	++++	Neg.	Neg.	++++	Neg.	Neg.
Inulin	++	Neg.	Neg.	++	Neg.	Neg.	++++	Neg.	Neg.	++++	Neg.	Neg.	++++	Neg.	Neg.
Lactose	++	Ac.	Neg.	++	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.
Levulose	+++	Ac.	Neg.	+++	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.
Litmus milk	−[3]	—	—	−[4]	—	—	−[5]	—	—	−[6]	—	—	−[7]	—	—
Maltose	++	Ac.	Neg.	++	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.
Mannitol	++	Neg.	Neg.	++	Neg.	Neg.	++++	Neg.	Neg.	++++	Neg.	Neg.	++++	Neg.	Neg.
Methyl red	+++	Pos.	—	+++	Pos.	—	++++	Pos.	—	++++	Pos.	—	++++	Pos.	—
Nitrate reduction	Pos.	—	—	Pos.	—	—	Pos.	—	—	Pos.	—	—	Pos.	—	—
Raffinose	++	Neg.	Neg.	++	Neg.	Neg.	++++	Neg.	Neg.	++++	Neg.	Neg.	++++	Neg.	Neg.
Rhamnose	++	Neg.	Neg.	++	Neg.	Neg.	++++	Neg.	Neg.	++++	Neg.	Neg.	++++	Neg.	Neg.
Saccharose	+	Neg.	Neg.	+	Neg.	Neg.	++++	Neg.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.
Sorbitol	++	Neg.	Neg.	++	Neg.	Neg.	++++	Neg.	Neg.	++++	Neg.	Neg.	++++	Neg.	Neg.
Tartrate	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	++++	Neg.	Neg.	++++	Neg.	++++	Neg.	Neg.	Neg.
Urease	+	Ac.	Neg.	+	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.	++++	Ac.	Neg.
Voges-Proskauer	+++	Neg.	—	+++	Neg.	—	+++	Neg.	—	+++	Neg.	—	+++	Neg.	—
Xylose	++	Neg.	Neg.	++	Neg.	Neg.	++++	Neg.	Neg.	++++	Neg.	Neg.	++++	Neg.	Neg.

[1] Hemolytic. [2] Complete liquefaction in 3 days. [3] Acid; coagulated. [4] Reduced to leuco-base; coagulated. [5] Reduced to leuco-base; partial liquefaction. [6] Reduced to leuco-base; 50 per cent liquefaction. [7] Alkaline curd; 50 per cent liquefaction.

10. A number of attempts were made to find a medium that the organism would ferment. None of these was successful. Although the organism resulted in the production of gas when it was inoculated into raw sludge, no gas was produced if the sludge had been previously sterilized at a pressure of 175 lb. per sq. in. for 30 min.

As indicated by its morphological, biochemical, and cultural reactions, this organism belongs to the genus *Bacillaceae*. Since no reference has been found in the literature indicating that this organism has been previously isolated, *Bacillus endorhythmos* is suggested for its name.

Digestion of Sewage Sludge

The organism was inoculated in 300-ml. portions of raw sewage sludge. In several instances gas was produced within the short period of 2 hr. As the organism did not produce gas in any of the 29 media, there is no indication that it is a gas producer. It is believed that the organism acts in synergism with other organisms responsible for the gasification of the sludge.

Growth Phase

The organism grew well in a special broth culture at 20°, 37°, and 44° C. At 20° C. the organism grew well within 24 hr. At this temperature the endobodies varied from 0.3 to 0.6 micron in length and from 0.1 to 0.3 micron in diameter.

At 37° C. good growth was observed within 4½ to 5 hr. The endobodies were somewhat larger, varying from 0.5 to 0.8 micron in length and from 0.1 to 0.4 micron in diameter. The cells were single and in chain formation, with moving bodies inside the cells. Motility of the organism was more pronounced at 37° C.

At 44° C. growth occurred within 4 hr. At this temperature the endobodies varied from 0.5 to 1.0 micron in length and from 0.1 to 0.4 micron in diameter. Motility and pleomorphism was greatest at this temperature. These results indicate that the organism was a thermophile. One of its unusual characteristics was that it grew well over a wide temperature range.

Effect of pH of Medium

Special medium in two duplicate groups of 16 tubes was adjusted with 0.1N hydrochloric acid solution or 0.1N sodium hydroxide solution to pH values ranging from 4.0 to 11.5, inclusive. Each tube was inoculated with a 24-hr. culture of the organism and incubated for 24 hr. at 35° C. and 44° C. At these temperatures there was very good growth at pH values between 5.0 and 9.5 and fair growth at a pH of 10.0. There was no growth at a pH of 4.5 or less, or at a pH of 10.5 or higher.

Thermal Death Time

A group of tests was made to determine the thermal death time of the organism. Eighteen-hour cultures, containing many vegetative cells and spore-like bodies as indicated by Gram and Mallory stains, were subjected to three temperatures. The organism was kept in a constant-temperature water bath at 68° ± 0.2 C. for 3½ hr. during the first test, and at 85° ± 0.2° C. for 5 hr. and 10 min. during the second test. The organism survived both temperatures for the time indicated.

In the third test the organism was exposed to a temperature of 95° ± 0.2° C. Organisms exposed to this temperature for 10 min. showed good growth when reinoculated and incubated for 24 hr. at 35° and 44° C. Exposure for 15 min. resulted in poor growth when reinoculated and incubated for 24 hr. at 35° C. and good growth when incubated for 24 hr. at 44° C. When the organism was exposed for 20 min. to a temperature of 95° ± 0.2° C., it failed to grow after it was reinoculated and incubated at 35° or 44° C. for 24 hr. All of the

foregoing tests were repeated three times with no deviation in the results.

Pathogenicity

Mice, guinea pigs, and rabbits were inoculated intramuscularly and intraperitoneally with 0.5-ml. portions of a 24-hr. heart-infusion broth culture of washed organisms to determine if they were pathogenic. Control animals were inoculated with sterile broth. All animals were observed daily except Saturday and Sunday for 21 days and then weekly for 4 months. As these animals were normal as far as could be ascertained at the end of the observation period, it is concluded that the organism was non-pathogenic to these animals.

Cellulose Digestion

Duplicate sets of tubes with screw caps containing (a) an elm leaf, (b) Whatman's filter paper No. 4 (c) blades of grass, and (d) non-absorbent cotton were inoculated with the organism and incubated for 60 days at 35° C. Although good growth occurred in all the tubes, no decomposition of the cellulose was observed when using a Greenough microscope (30X). It was concluded, therefore, that the organism is not a cellulose digester.

Alcohol Tolerance

Special broth cultures, which were 24-hr. old, were inoculated into 11 tubes containing 0 to 10 per cent of 95 per cent ethyl alcohol and incubated for 24 hr. at 35° and 44° C. Good growth was observed at both temperatures when the concentration of alcohol was 4 per cent or less. At a temperature of 35° C. the growth was fair at a concentration of 5 per cent and very slight at concentrations between 6 and 8 per cent, inclusive. There was no growth when the concentration was 9 per cent or higher. At a temperature of 44° C. there was no growth when the concentration of alcohol was 5 per cent or higher. No gas was evolved during any of the foregoing tests. Identical results were obtained when duplicate tests were made.

Utilization of Fatty Compounds

One gram of each of the following fatty compounds was autoclaved at 121° C. for 15 min., tested for sterility, and placed in vials containing a good growth of the organism:

1. Olive oil.
2. Butter.
3. Soy-bean oil.
4. Linseed oil.
5. Lard.
6. Cottonseed oil.

The materials were incubated at 37° and 44° C. for 21 days and shaken twice daily except on holidays. No disintegration or utilization of the fatty materials was observed.

Conclusion

1. A liquefying, facultative anaerobic, non-pathogenic bacillus, that grows singly and in chains, was isolated from digesting sewage sludge. The organism, which was quite motile, grew over a wide temperature and pH range. It did not produce gas in any of the inoculated media. It liquefied and gasified raw sewage sludge. However, when sterilized raw sludge was inoculated with the organism, no gas was produced. It is possible that the organism functions in synergism with gas-producing bacteria.

2. This organism is unusual in that it contains motile endobodies.

3. No reference has been found in the literature indicating that this organism has been previously isolated.

4. The morphological, biochemical, and cultural reactions of this organism indicate that it belongs to the genus *Bacillaceae*. *Bacillus endorhythmos* is suggested for its name.

Acknowledgments

The investigation described in this paper is part of a program involving the study of the biological factors responsible for the digestion of sewage sludge at the Back River sewage treatment works, which is under the general supervision of P. L. Holland, director, Department of Public Works, Baltimore, Md., and John J. Hunt, sewerage engineer. Abel Wolman is consultant to the Department of Public Works. Material assistance in conducting these experiments was rendered by the Baltimore City Health Department, of which Dr. Huntington Williams is Commissioner and Clinton L. Ewing is director of the Bureau of Laboratories. R. J. Trautman, principal associate engineer, has direct supervision of the sewage works and Paul L. Smith is plant superintendent.

References

1. Salle, A. J., "Fundamental Principles of Bacteriology." 3rd Ed., p. 126 (1948).
2. "Standard Methods for the Examination of Water and Sewage." 9th Ed. Amer. Pub. Health Assn., New York, N. Y. (1946).

NON-MEMBER MEETINGS OF INTEREST

Courses on the biology of sewage and stream sanitation, under the direction of Professors H. Liebmann and R. Demoll, will be held at the Bavarian Biological Experiment Station, Veterinärstr. 6, Munich 22, Germany. An introductory course is scheduled for March 8–12, 1954, with an advanced course during the period October 4–8, 1954. Closing date for reservations for the introductory course is February 15, 1954; for the advanced course, September 15, 1954. Further details are obtainable from Professor Liebmann at the address given.

The Third Southern Municipal and Industrial Waste Conference will be held at North Carolina State College, March 18–19, 1954. Details are available from Professor Nelson L. Nemerow, Department of Civil Engineering, North Carolina State College, Raleigh, N. C.

A one-day Conference on Instrumentation in Water, Sewage, and Industrial Waste Treatment is to be held on April 22, 1954, at Manhattan College, New York, N. Y. The event is planned to bring together both makers and users of instruments for water purification and waste treatment. Additional information may be obtained from: Civil Engineering Dept., Manhattan College, New York 71, N. Y.

The Fourth Inter-American Conference of Sanitary Engineering, organized by the Inter-American Association of Sanitary Engineering, will be held July 25–31, 1954, at Sao Paulo, Brazil. Detailed information may be secured by contacting the General Secretariat, Fourth Inter-American Conference of Sanitary Engineering, Postal Box 8099, Sao Paulo, Brazil.

Industrial Wastes

PROCESS ENGINEERING IN STREAM POLLUTION ABATEMENT *

By A. N. Heller and M. E. Wenger

Barrett Division, Allied Chemical and Dye Corp., New York, N. Y.

During the past three decades material progress has been made by a number of industries in the utilization of their process liquid wastes. In general, this has resulted in new products, improvement in operations, and a reduction in the pollutional characteristics of the industrial wastes. Industrial processes which probably best typify the feasibility of the chemical engineering approach are fermentations, pulp and paper manufacture, corn starch processing, and by-product coke oven operations. In each instance, comparative economics of recovery *versus* industrial waste treatment emphasized the feasibility of process engineering as the first approach to the reduction of the pollutional characteristics of the industrial wastes.

The purpose of this paper is to show that in the manufacture of an organic chemical, such as synthetic phenol, the liquid (process) wastes were amenable to control by the application of the principles of process engineering. Comparative economics of process engineering *versus* industrial waste treatment reemphasized the feasibility of the process approach, initially, to the solution of a complex industrial waste problem.

* Presented at 1953 Annual Meeting, Pennsylvania Sewage and Industrial Wastes Assn.; State College, Pa.; Aug. 26–28, 1953.

Historical

The primary source of "natural" phenol, prior to 1888, was from the thermal decomposition of coal tar. Other natural sources now in use are shale oil and petroleum. It was not until World War I that the primary use of phenol in disinfectants and explosives (picric acid) changed to phenolic resins. The new demand shifted production from the "natural" to the synthetic product. In 1952, 85 per cent of the world production of phenol was by synthetic processes, and 75 per cent of this phenol was produced in the United States (1).

Since 1918 numerous investigations have been made to determine the effect of phenolics on a water supply. The primary effect still appears to be the imparting of unpleasant tastes and odors to drinking water by traces of phenol; that is, 0.1 p.p.m. of phenol to as low as 3.0 p.p.b. chlorophenol (2). During the past few years, it has become increasingly evident that the allowable discharge of phenolics to a surface supply, from an industrial establishment, has reached a restrictive level of such magnitude that compliance imposes a most severe cost penalty. If the previously mentioned trend in control of phenolic discharges is coupled with a simultaneous trend towards the increasing productive demands for phenol, as a basic raw

material, then it behooves everyone to re-examine carefully the methods of abatement—process control and treatment—as well as the allowable loadings of phenolics from industrial establishments to receiving streams.

Manufacture of Phenol

Essentially, all of the "natural" phenol is produced by the thermal decomposition of more complex organic substances. All of the current commercially produced synthetic phenol stems from the hydroxylation of benzene.

There are at least four methods now in commercial use for the conversion of benzene to phenol (1), as follows:

1. Sulfonation of benzene, followed by fusion with molten caustic to form the sodium phenolate salt.
2. Chlorination of benzene, followed by hydrolysis in alkaline solution.
3. The regenerative process, in which chlorobenzene is catalytically hydrolyzed and the product, hydrochloric acid, is used for chlorination of benzene.
4. Cumene process.

Table I presents the principal chemical reactions involved in the commercial synthesis of phenol (3). It is evident that in each process the by-products produced differ markedly; consequently, the industrial (liquid) process wastes also will differ in their pollutional characteristics. The only common denominator is the basic raw material—benzene—and the product—phenol.

Definition of the Problem—Sulfonation Process

This paper concerns itself only with the sulfonation process. These studies were carried out at the Frankford works, Barrett Division, Allied Chemical and Dye Corp., Philadelphia, Pa. The synthetic phenol plant is only one among many of the operations resident within the Frankford works. The industrial wastes discharge into

TABLE I.—Chemical Reactions for Synthesis of Phenol

1. Sulfonation:

$$C_6H_6 + H_2SO_4 \rightarrow C_6H_5SO_3H + H_2O$$
$$2C_6H_5SO_3H + Na_2SO_3 \rightarrow 2C_6H_5SO_2Na + SO_2 + H_2O$$
$$C_6H_5SO_2Na + 2NaOH \rightarrow C_6H_5ONa + Na_2SO_3 + H_2O$$
$$2C_6H_5ONa + SO_2 + H_2O \rightarrow 2C_6H_5OH + Na_2SO_3$$

2. Chlorobenzene-alkaline process:

$$C_6H_6 + Cl_2 \rightarrow C_6H_5Cl + HCl$$
$$C_6H_5Cl + Na_2CO_3 + H_2O \rightarrow C_6H_5OH + NaCl + NaHCO_3$$

or

$$C_6H_5Cl + 2NaOH \rightarrow C_6H_5ONa + NaCl + H_2O$$
$$C_6H_5ONa + HCl \rightarrow C_6H_5OH + NaCl$$

3. Regenerative (Raschig) process:

$$C_6H_6 + HCl + \tfrac{1}{2}O_2\ (Air) \xrightarrow[Cat.]{Cu\text{-}Fe} C_6H_5Cl + H_2O$$
$$C_6H_5Cl + H_2O \xrightarrow[Cat.]{SiO_2} C_6H_5OH + HCl$$

4. Cumene process:

$$C_6H_5C(CH_3)_2OOH \xrightarrow{Cat.} C_6H_5OH + (CH_3)_2CO$$

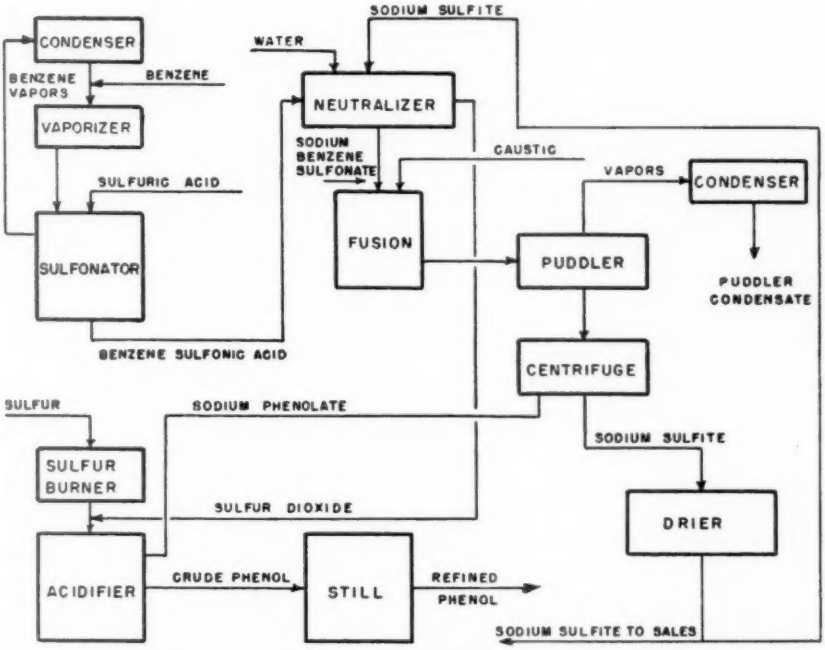

FIGURE 1.—Schematic flow diagram of sulfonation process for producing synthetic phenol.

Frankford Creek, which empties into the Delaware River.

As a result of a comprehensive industrial waste survey carried out early in 1948, it became evident that one of the major constituents of the industrial wastes from the Frankford works was phenolic compounds. An analysis of the various departments handling and producing phenolic materials disclosed that the industrial (process) wastes from the synthetic phenol plant were one of the primary contributors. On this basis, a detailed process study was initiated to define the magnitude of pollution emanating from the synthetic phenol plant.

Figure 1 is a schematic flow diagram

TABLE II.—Industrial Waste Characteristics—Synthetic Phenol Plant (1948)

Process Stream	Vol. gal./yr.	Major Constituents (1,000 lb./yr.)					
		Phenol	Phenolics	NaOH	Sodium Benzene Sulfonate	SO_2	Na_2SO_3
Spent sulfonator scrubber NaOH	535,000	—	—	75	57	—	355
SO_2 scrubber effluent	1,705,000	—	—	—	—	280	—
Puddler condensate	355,000	22	—	—	—	—	—
Sulfite liquor	1,190,000	130	—	—	150	—	2,245
Drier scrubber effluent	12,883,000	250	—	—	—	—	705
Phenol still boil-out	1,740,000	450	280	—	530	—	—
Total	18,408,000	852	280	75	737	280	3,305
Parts per million	—	5,540	1,820	455	4,800	1,820	21,400

of the sulfonation process for production of synthetic phenol. This process may be broken down into eight unit operations as follows:

1. Sulfonation of benzene with sulfuric acid to form benzene sulfonic acid.
2. Neutralization of the benzene sulfonic acid with sodium sulfite to form sodium benzene sulfonate, sulfur dioxide, and water.
3. Fusion of the sodium benzene sulfonate with molten anhydrous caustic to form sodium phenate and sodium sulfite.
4. Puddling of the molten fusion mass in a sodium sulfite solution to produce a solution of sodium phenate and to precipitate the sodium sulfite.
5. Centrifuging of the puddled mass to separate the sodium sulfite crystals from the sodium phenate-sodium sulfite solution.
6. Acidification of the sodium phenate-sodium sulfite solution with sulfur dioxide gas (from Step 2) to convert the sodium phenate to phenol.
7. Distillation of the crude synthetic phenol to produce refined phenol.
8. Drying of the centrifuged sodium sulfite cake.

Table II presents the volume and major constituents of the industrial wastes as of 1948. It is to be noted that, in terms of phenolics, the major contributor (64 per cent) is the phenol still boil-out. This phase of the project will be discussed herein in detail as an example of the process approach to solution of a major industrial waste problem. In a subsequent section, the over-all effect of process engineering on stream pollution abatement of the synthetic phenol plant is summarized.

Development of the Phenol Still Boil-out Process

Prior to June, 1949, the distillation residue was removed from the still by using three washes of 2,500 gal. each of fresh water (a total of 7,500 gal. per run, or 1,515 m.g. per year). The cold water was charged to the still, heated to boiling, and then a solution of the distillation residue was discharged to Frankford Creek. The resultant phenol still boil-out solution contained approximately 4 per cent phenolics and dissolved organic and inorganic salts. Use of three separate washes was required to effect complete solution and removal of the distillation residue, since the salts were not completely soluble in a single wash.

Laboratory investigation of the boil-out process demonstrated that one part of the distillation residue was completely soluble in five parts of water, when the water was charged at 95° C. The distillation residue, however, was only partially soluble when the water was charged cold and then heated to 95° C. The proportions used in the foregoing laboratory studies approximated the ratio of water to residue for one wash of the plant boil-out process.

A tank was connected temporarily to the phenol still system to permit heating of the wash water to 95° C. prior to admission to the still for boil-out purposes. Extensive plant-scale testing of the use of 95° C. water demonstrated that the still was cleaned adequately with one wash of 3,000 gal. This process modification resulted in a 66.6 per cent reduction in the number of washes and a 60.0 per cent reduction in the quantity of fresh water utilized in the process.

Acidification of the concentrated boil-out solution, on a laboratory basis, with sulfuric acid, sulfur dioxide, and hydrochloric acid resulted in separation of the solution into two phases. One phase was chiefly phenolics, and the other an aqueous solution of phenolics and salts. Decantation effected removal of a portion of the phenolics. The percentage removal was dependent on the concentration of phenolics in the boil-out solution. An increase in concentration from 8 to 12 per cent phenolics increased the removal from

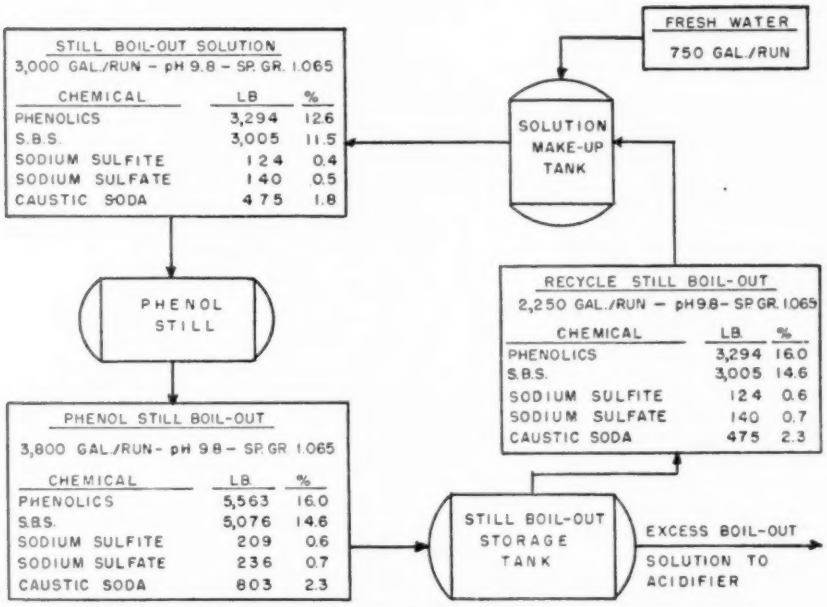

FIGURE 2.—Flow sheet and material balance for recycle boil-out process.

35 to 85 per cent. These data indicated the feasibility of recycling the plant boil-out solution and thereby improving the potential recovery of phenolics.

Additional tank capacity was provided, therefore, to recycle the boil-out solution. After extensive testing, the final proportions for the boil-out solution charged to the still were fixed at the following values:

Recycled boil-out solution	2,250 gal.
Water	750 gal.
Total	3,000 gal.

The foregoing represent a 90 per cent reduction in the quantity of water required for the boil-out procedure, and the concentration of phenolics in the solution increased from 4 to 16 per cent. The still boil-out cycle was reduced from 4.5 to 1.75 hr. A saving of approximately 600 distillation hours per year.

Inspection of the phenol still at frequent intervals showed that residue removal with one wash of recycled boil-out solution was efficient. In some cases a small quantity of undissolved residue was found in the still, but this was not considered sufficient to interfere with distillation of the next charge. In all cases, the steam coils were clean. The flow sheet and material balance for the recycled still boil-out procedure are given in Figure 2.

Facilities were installed to acidify the recycled boil-out solution with sulfuric acid in order to recover 75 to 85 per cent of the phenolics and also to prevent their discharge to Frankford Creek. Sulfuric acid was selected for economic and operating reasons.

Plant operations resulted in recovery of only 75 per cent of the phenolics from the recycled boil-out solution. This did not agree with laboratory data. Further laboratory studies were then initiated to determine methods for improving removal efficiency. Figure 3 shows that a decrease in pH of the aqueous layer and a decrease in

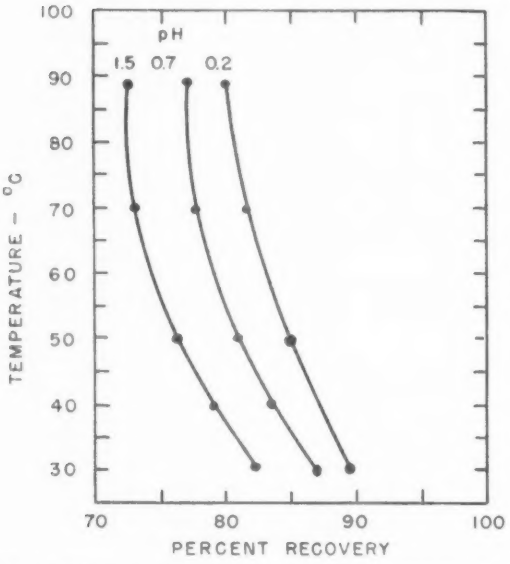

FIGURE 3.—Effect of temperature and pH on recovery of phenolics.

the temperature during springing resulted in increased removal of phenolics from the recycled boil-out solution. Maximum effect (+ 16.5 per cent) was obtained by decreasing the pH from 1.5 to 0.2 and the temperature from 90° to 30° C.

Plant tests confirmed the effect of

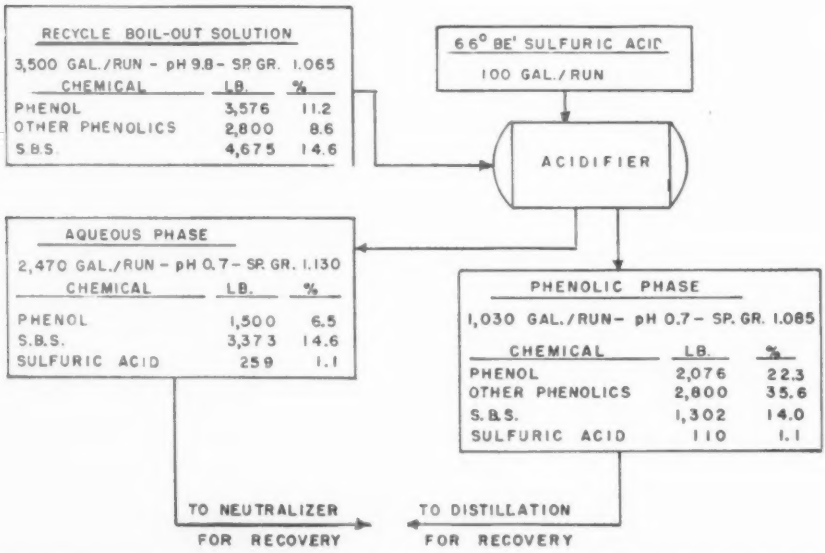

FIGURE 4.—Flow sheet and material balance for acidification of still boil-out solution.

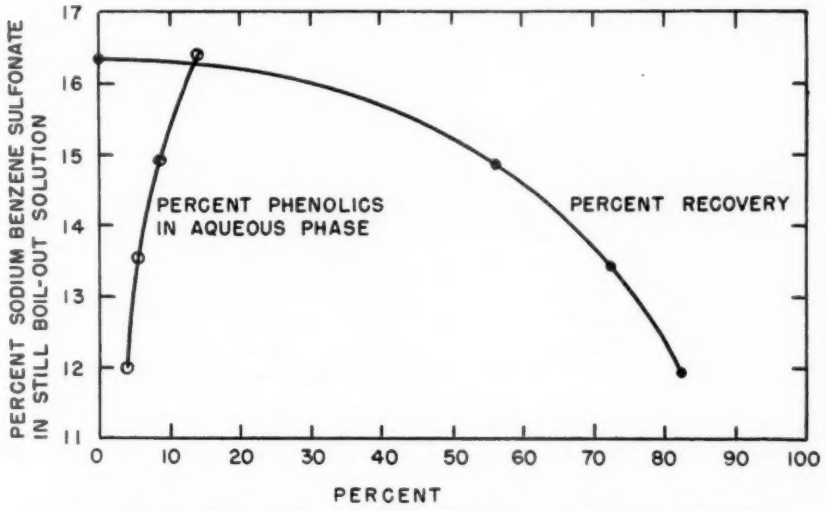

FIGURE 5.—Effect of sodium benzene sulfonate on recovery of phenolics.

pH reduction. The effect of temperature reduction could not be determined readily in the plant due to the lack of cooling facilities. However, one test was made in which the recycled boil-out solution was cooled to 50° C. by air agitation during a holding period of 48 hr. Upon addition of the sulfuric acid the temperature increased to 65° C. This test yielded the expected percentage removal of phenolics.

Although maximum removal of phenolics can be accomplished by acidification to pH 0.2 at 30° C., the operating procedure was established at pH 0.7 and 90° C., for the following reasons:

1. Cost of cooling facilities (estimated at $15,000) is not economically justifiable.

2. The lower pH would introduce additional sulfate ion into the synthetic phenol process upon projected containment of the aqueous layer produced in the acidification operation. The flow sheet and material balance for the acidification operation are given in Figure 4.

The effect of sodium benzene sulfonate concentration on the phenolic removal efficiency is shown in Figure 5. An increase in sodium benzene sulfonate concentration from 12.0 to 16.3 per cent resulted in an increase in phenolics in the aqueous layer from 4.0 to 13.3 per cent, and the removal efficiency was decreased from 82 to 0 per cent; that is, no phase separation occurred. These data indicated the necessity of process control to prevent accumulation of excess sodium benzene sulfonate in the still charge.

Recovery of Values

The recycled still boil-out solution contained approximately the following major chemicals:

Phenol	450,000 lb./yr.
Other phenolics	280,000 lb./yr.
Sodium benzene sulfonate	530,000 lb./yr.

The value of the foregoing is approximately $100,000 per year.

The phenolic phase separated during the acidification operation consisted of phenol, other phenolic compounds, and water. Laboratory and pilot-plant tests demonstrated the feasibility of recovery of a major portion of phenol by distillation. A plant-

scale test confirmed these data. Typical results follow:

Acid water fraction	28%
Phenol fraction	22%
Residue	50%
Total	100%

Still time for distillation of the recovered phenolics was made available by the reduction in the still boil-out time cycle.

The acid water fraction contained approximately 8 per cent by weight of phenol. Values were recovered by processing it with the acid water fraction produced in normal phenol still operations. The phenol fraction had a melting point of 39° C. Blending with plant crude phenol followed by redistillation produced specification phenol. The residue from the distillation was blended with other plant residues and processed for recovery of values.

The aqueous layer from the acidification operation contained mainly sodium benzene sulfonate (12 to 18 per cent) and approximately 2 to 8 per cent phenol. Because the neutralization of benzene sulfonic acid with dry sodium sulfite to produce sodium benzene sulfonate required the addition of fresh water, it was projected that (a) fresh water could be replaced with the aqueous layer from acidification and (b) containment of the solution at the neutralizer would result in recovery of the sodium benzene sulfonate and the phenol. These ideas were confirmed by plant-scale tests. The flow sheet and material balance for recovery of values are given in Figures 6 and 7.

Figure 8 depicts the flow sheet for the original boil-out process (1948) and for the process as it exists in 1953. It should be noted that a simple process has been greatly expanded and complicated. The highly pollutional characteristics (that is, phenolics) of the industrial wastes in 1948, however,

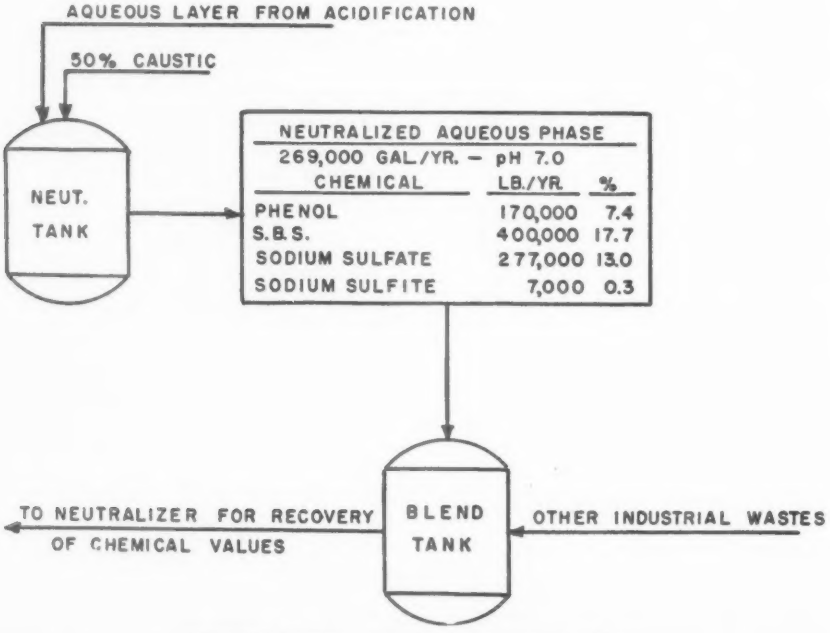

FIGURE 6.—Recovery of values in aqueous layer.

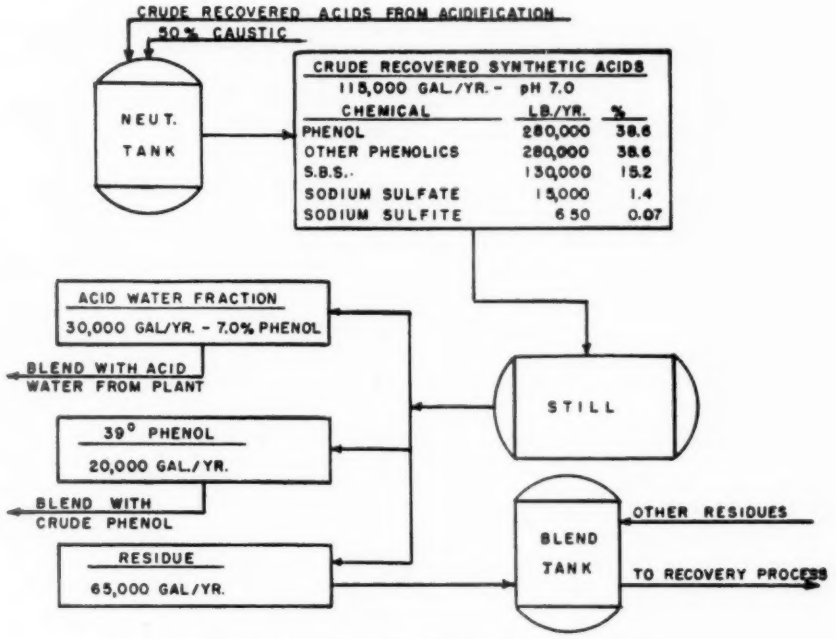

FIGURE 7.—Recovery of values in phenolic phase.

have been completely eliminated, and chemical values are being recovered. The only industrial waste from this operation is the acidic (non-phenolic) discharge from the scrubber on the acidification unit.

Capital expenditure for the foregoing process modifications was $35,000, with return to process of chemicals valued at approximately $75,000 per year.

Over-All Effect of Process Engineering

Although the preceding sections of this paper have dealt specifically with the still boil-out, it must be realized this process waste stream is only one of many from the operation of the synthetic phenol plant.

Continued application of process engineering to (a) water balance, (b) material balance, (c) heat balance, (d) product quality, and (e) unit operations resulted in a marked reduction in the volume and pollutional characteristics of the industrial wastes. Tables III and IV present the volume and chemical characteristics of the industrial wastes in 1948 and as they exist in 1953. It should be noted that (a) consumption of fresh water has been reduced 95.5 per cent (17.427 to 0.783 m.g. per year) and (b) the volume of industrial wastes has been re-

TABLE III.—Effect of Process Engineering on Water Balance and Industrial Wastes (1948–1953)

Source	Fresh Water, (m.g./yr.)		Industrial Wastes, (m.g./yr.)	
	1948	1953	1948	1953
1. Sulfonator Scrubber	0.112	0.112	0.535	0.535
2. Neutralizer	0.420	0	0	0
3. SO_2 Scrubber	1.087	0	1.705	0
4. Puddler	0.392	0	0.355	0
5. Centrifuge	1.178	0.050	1.190	0
6. Drier Scrubber	12.660	0.524	12.883	0
7. Still Boil-Out	1.515	0	1.740	0
8. Steam Distillation	0.063	0.097	0	0
Total	17.427	0.783	18.408	0.535

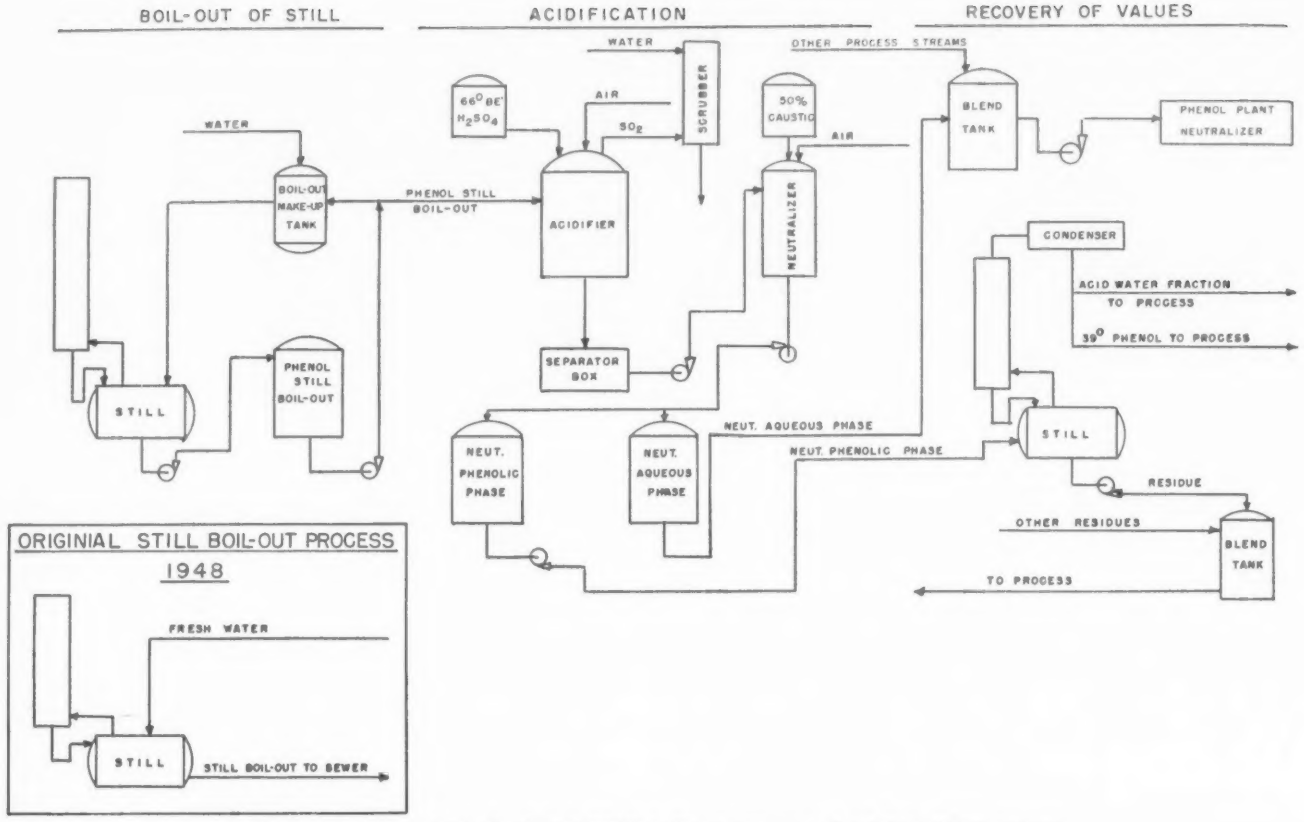

FIGURE 8.—Flow sheet of original (1948) boil-out process and existing (1953) process.

duced 97.1 per cent (18.408 to 0.535 m.g. per year). The reduction in discharge of chemicals equates to 91.2 per cent of the 1948 discharge; that is, from 5,529,000 to 487,000 lb. per year. (see Table IV).

It also should be noted that phenol and other phenolic compounds, as well as sulfur dioxide, have been completely eliminated from the industrial waste discharges.

In addition to stream pollution abatement, containment of industrial wastes resulted in an increase of approximately 5 per cent in theoretical yield based on benzene consumed.

The over-all project cost estimates $100,000, with a return to process of chemicals valued at $112,000 per year.

TABLE IV.—Discharge of Chemicals

Chemical	1,000 lb. per Year		Reduction (%)
	1948	1953	
Phenol	852	0	100.0
Other phenolics	280	0	100.0
Sodium sulfite	3,305	355	89.3
Sodium benzene sulfonate	737	57	92.3
Sodium hydroxide	75	75	0.0
Sulfur dioxide	280	0	100.0
Total	5,529	487	91.2

Summary and Conclusions

In the manufacture of synthetic phenol by the sulfonation process, the liquid (process) wastes were essentially eliminated by the application of the principles of process engineering. The economics of this approach, *per se*, were justifiable; that is, total cost of project ($100,000) compares with a return of $112,000 per year.

A major phase of the over-all stream pollution abatement program at the Frankford works has been completed, particularly as it relates to the discharge of phenolic compounds.

An improved process for the boil-out of the still bottom, synthetic phenol plant, permitted the elimination of 64 per cent of the phenolics from the synthetic phenol plant wastes. Extensive laboratory, pilot, and plant studies enabled the recovery of the major chemical values economically; that is, a capital investment of $35,000 returned $75,000 per year.

The step-wise approach, both as to technology, as well as to time of accomplishment, was productive of stream pollution abatement and improvement in the operations of the synthetic phenol plant.

Acknowledgment

The authors wish to acknowledge the contribution of the staff of the Frankford works to the successful conclusion of the stream pollution abatement program of the synthetic phenol plant.

References

1. Kirk, R. E., and Othmer, D. F., "Encyclopedia of Chemical Technology." Vol. 10, The Interscience Encyclopedia, Inc. (1953).
2. Rudolfs, W., "Industrial Wastes, Their Disposal and Treatment." A.C.S. Monograph No. 118, Reinhold Publishing Corp., New York, N. Y. (1953).
3. Faith, W. L., Keyes, D. B., Clark, R. L., "Industrial Chemicals." John Wiley and Sons, New York, N. Y.

TREATMENT OF COMPLEX METAL–FINISHING WASTES *

By K. S. Watson

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Prior to 1948, the General Electric Company at Erie, Pa., discharged industrial wastes into three open ditches, which flowed into Lake Erie. During that year, plant management inaugurated a course of action to improve plant wastes that had been under consideration for some time. Efforts to solve the problem had lead prior to this time to the provision of some acid neutralization facilities and two chlorinators for cyanide treatment. Concerted waste improvement action was launched in 1948 because plant management wanted to eliminate the possibility of anyone being adversely affected by waste materials carried in any of the industrial effluents.

Early in 1948, representatives of the Erie plant asked the Pennsylvania Sanitary Water Board for counsel on the best manner of correcting its waste problems. After considerable negotiations with the state authorities, agreement was reached on the degree and type of treatment necessary.

A consulting engineering firm was retained in May, 1949, to design a waste treatment plant for the Erie works. Construction was started on the plant in May, 1950, and was completed in April, 1951. The completed plant and the collection system serving it had a total cost of $705,000.

This Erie treatment plant has now been in operation for two and one-half years. Therefore, it seems desirable to summarize some of the operating experiences there for any benefits such a summary might have for others faced with a similar problem.

The industrial wastes at the Erie Plant have their origin in pickling, plating, bonderizing, anodizing, and other metal-finishing operations. Since this is the case, the wastes carry acids, cyanides, and metal ions, including chromium and copper of sufficient concentration that treatment for each of these materials was provided.

For the purposes of this paper, the discussion of waste facilities is broken down into the collection system, the treatment plant, and the cost of constructing and operating these facilities.

Collection Systems

Three separate waste collection systems have been provided at the Erie plant. The first of these handles spent pickling acids. A portion of such spent acids when discharged flow into sumps, from where they are pumped to the treatment plant. The remainder of the acid, from other portions of the plant, flows into storage tanks, from which it is picked up by two tank trailers (Figure 1) and hauled to the treatment plant.

The second system consists of a series of steel or concrete sumps or tanks located at each plating installation to collect all rinse water containing cyanide. These tanks are served by duplicate pumps, which eject the cyanide rinse water overhead through 4,700 ft. of various-sized pipe to the treatment plant.

* Presented at 26th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Miami, Fla.; Oct. 13–16, 1953.

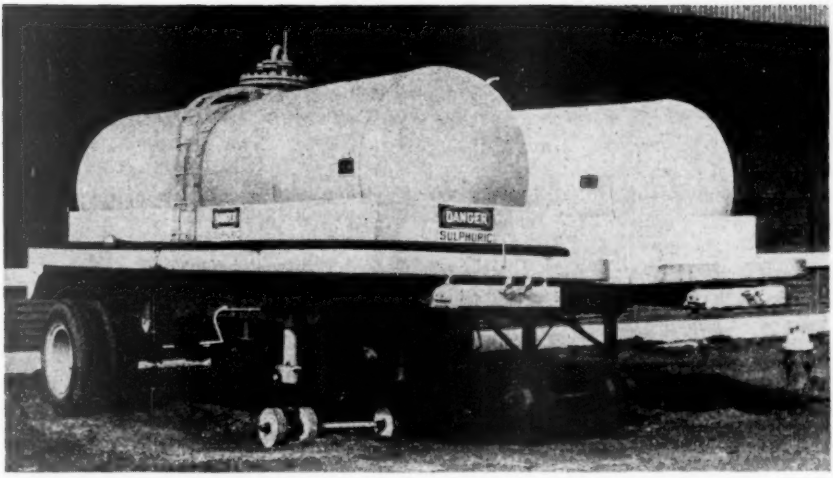

FIGURE 1.—The two tank trailers available at Erie to transport spent acids from their point of use to the neutralization plant.

The third system is a series of acid-brick-lined concrete tanks at each plating installation discharging chromium, aluminum, and copper rinse water. These sumps collect the metal-bearing rinses. These waters are then pumped overhead by duplicate acid-resistant pumps through 6,800 ft. of various-sized rubber and Saran-lined pipe to the treatment plant.

This segregation at Erie into a series of collection systems is a similar approach to that being used in many plants treating metal-finishing wastes.

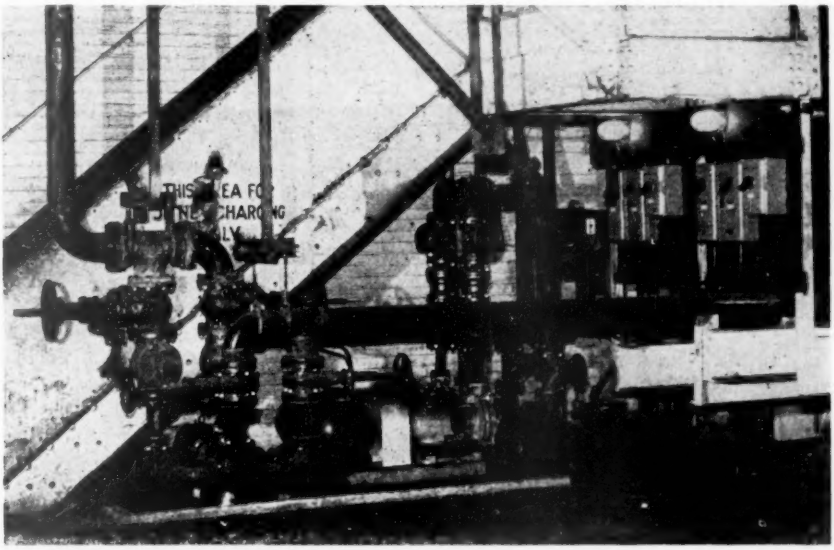

FIGURE 2.—Cyanide and metal rinse-water sumps and pumps and lines to deliver wastes overhead to the treatment plant.

The exact type of collection is perhaps unique, however, since the rinse waters are picked up and transported overhead to the treatment plant. This overhead system to the outside of the buildings was used to eliminate the labor and cost which would have been necessary to provide for transmission of the wastes under the floor and around equipment. Overhead transportation of the wastes on the outside of the buildings is practiced at Erie because extensive conveyor and steamline trestles are available to carry the waste lines. The method of conveying most of the spent acid to the treatment plant is also somewhat unusual, in that this acid is actually picked up in lead-lined tank trailers equipped with pumps and hauled to the plant. This step was taken to avoid the piping difficulties already mentioned. Figure 2 shows the sump, pumps, and lines going overhead to convey cyanide and metal rinse waters from one location to the treatment plant.

All process wastes requiring treatment are picked up in the systems already outlined. Since this is the case, the original process-water sewer system is used to collect all the remaining water not requiring treatment and bypass it around the treatment plant to Lake Erie. The sanitary sewage is discharged into the Erie sanitary sewer system by a separate sewer system within the plant provided before industrial waste treatment was considered.

The Treatment Plant

Metal Rinses

The metal rinses, including those waters carrying chromium, which are picked up in the system already described, are collected in a 232,000-gal. holding tank. During the first shift of a normal operating day something over 250,000 gal. of rinse water which is acid in nature is pumped from the holding tank through a 8,625-gal. tank containing an agitator. In this tank an average of 13.7 lb. of copperas (67.37 per cent $FeSO_4$) is fed and mixed with the waste for each pound of chromium it carries. The reaction

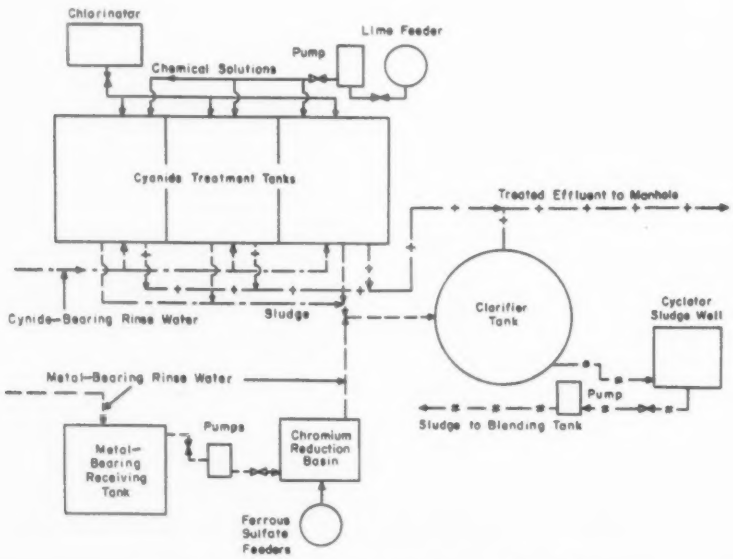

FIGURE 3.—Rinse-water treatment, Erie works.

TABLE I.—Average Daily Chromium Waste Treatment Results Erie Plant, General Electric Co., 1952*

Month	Metal-Bearing Rinse Wastes (g.p.d.)	$FeSO_4$ Used (lb.)	Chromium Conc.** before Treat. (p.p.m.)	Daily Chromium Conc.** in Eff. (p.p.m.)	
				Max.	Min.
July	285,531	197.91	5.9	0.08	0
Aug.	278,833	188.88	6.1	0.05	0
Sept.	277,691	163.04	6.2	0.03	0
Oct.	253,160	120.00	5.0	0.02	0
Nov.	236,476	115.47	3.5	0.03	0
Dec.	265,000	133.92	3.7	0.70	0
Av.	266,115	153.20	5.06	0.15	0

* Discharge takes place on an average of 5 days per week.

** As hexavalent chromium.

and mixing tank provides a 10-min. reaction period for reducing the hexavalent chromium present to the trivalent form. All the metal-bearing rinse waters are treated for chromium reduction rather than providing a separate collection system for the chromium rinses alone.

The metal-bearing rinse waters then flow into a 50-ft. diameter clarifier tank along with other wastes, where lime is fed to neutralize acidity and precipitate the metals present. Figure 3 shows the course of the metal rinse waters as they pass through the treatment plant. Table I, which summarizes chromium operations for the last half of 1952, shows that there was an average metal-bearing rinse-water discharge, including chromium rinses, of 266,115 g.p.d. Such a discharge normally takes place on an average of five days per week. The average hexavalent chromium concentration of this rinse water prior to treatment was 5.06 p.p.m. After treatment, the effluent contained less than 0.1 p.p.m. of hexavalent chromium.

The supernatant liquid from the clarifier is discharged to Lake Erie. The sludge from the tank is pumped to a special sludge system, where it is handled as outlined under the section describing sludge handling.

Cyanide Rinses

The cyanide rinses, which are delivered to the plant by the system already discussed, flow into one of three 205,000-gal. alternate batch treatment tanks. Facilities for the batch treatment of cyanide wastes were provided at Erie because representatives of the Pennsylvania Sanitary Water Board indicated that the continuous treatment of such wastes was not considered satisfactory in Pennsylvania. When a volume of 200,000 gal. accumulates in a tank, it is tested for cyanide content. Then interconnected cyanide and lime solution pumps are started, and the raw cyanide waste is pumped through the chlorinators, being injected continuously, before reaching the chlorinators, with sufficient lime to insure that the pH has been raised to 8.5 or above and maintained at that level in the tank. Three pounds of chlorine per pound of cyanide is fed to the mixture as it passes through the chlorinators and is returned to the batch treatment tank through rubber-lined pipe. This cycle continues for 3 hr., during which

TABLE II.—Average Cyanide Waste Treatment Results Per Cyanide Tank Discharged, 1952*

Month	Cyanide Rinse Water Per Tank (gal.)	Chlorine Used (lb.)	Cyanide Concentration		
			Before Treatment (p.p.m.)	Effluent (p.p.m.)	
				Max.	Min.
July	200,000	144	22.9	0	0
Aug.	200,000	232	46.3	0	0
Sept.	—†	—†	—	—	—
Oct.	200,000	154	37.5	0	0
Nov.	200,000	142	29.0	0	0
Dec.	200,000	142	25.9	0	0
Av.	200,000	162.8	32.5	0	0

* Twenty tanks of cyanide were discharged during the latter half of 1952. A cyanide rinse discharge from the treatment plant took place on a total of 16 days during the period.

† No discharge; vacation period.

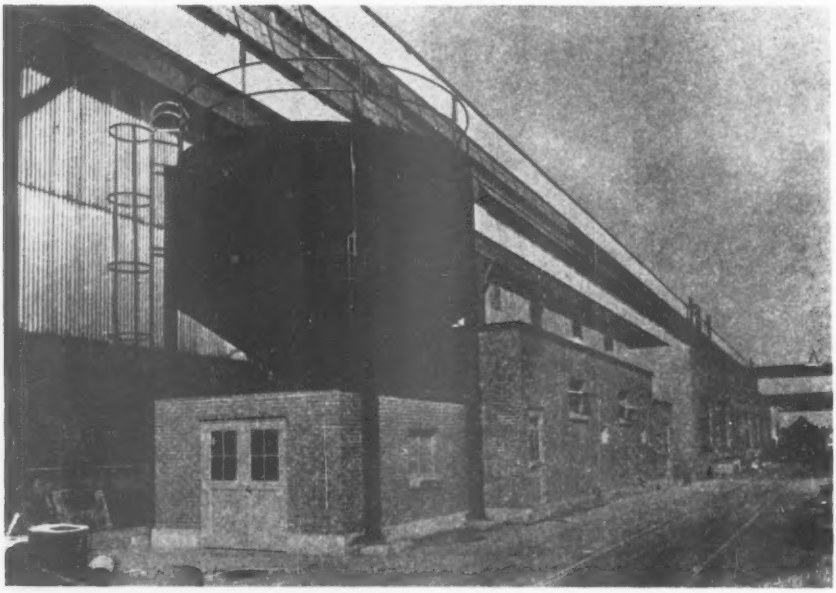

FIGURE 4.—The two small brick buildings (foreground) house the two acid neutralization tanks at Erie and the chemical feeders and other appurtenances to make them function.

period agitation is continuously carried out in the treatment tank. Agitation is continued for 30 min. after the chlorination cycle has been completed. The tank is next permitted to stand for at least 4 hr. Next, the upper two-thirds of the volume of the tank is decanted to Lake Erie. Following this, it was the original intention that the lower one-third of the tank, including the sludge, be pumped to the clarifier to be mixed with the rinse water already discussed. Operating experience has shown, however, that the sludge need not be drawn from the cyanide tank after each batch is treated. In fact, sometimes as many as eight batches of cyanide rinse water are treated before any sludge is pumped to the clarifier. The flow of the cyanide rinses is shown in Figure 3.

Table II summarizes cyanide operating results during the last half of 1952. Only 20 tanks of treated cyanide rinse water were discharged during this half-year period so discharges took place on only 16 different days. The summary indicates that the average cyanide concentration of this rinse water as it flowed to these treatment tanks was 32.5 p.p.m. The treatment given the wastes in the treatment tanks

TABLE III.—Pickle Liquor Neutralization Results, 1952*

Month	Liquor Req. Neutralization (gal.)	pH		Lime Required (lb.)
		Before Treat.	After Treat.	
July	63,000	1.0	9.9	23,250
Aug.	46,000	1.0	10.1	23,150
Sept.	43,500	1.0	10.0	22,000
Oct.	55,000	1.0	9.9	20,500
Nov.	40,000	1.3	10.1	8,000
Dec.	63,000	1.0	10.2	15,000
Total	310,500	—	—	111,900

* Pickle liquor was neutralized and pumped into the sludge handling system on 22 days during this half-year period.

reduced the cyanides to zero on every occasion.

Spent Pickle Liquor

The spent pickle liquor, as indicated previously, is conveyed by pipe or mobile tank to one of two holding tanks of 10,000- and 15,000-gal. capacity for neutralization. The neutralization facilities are housed in the building shown in Figure 4. Feeding equipment is available at the acid plant to permit the feeding of ferrous sulfate in case a batch of acid requiring neutralization contains chromic acid of consequence. The acid neutralization units are separated about 875 ft. from the main waste treatment plant. This separation of facilities was decided upon to permit advantage to be taken of existing neutralization tanks, which had been installed in the initial early efforts made by the plant to correct the acid problem.

Table III summarizes pickle liquor neutralization activities as carried out at Erie. A total of 310,500 gal. of spent pickle liquor was neutralized during the last half of 1952. This neutralization required 111,900 lb. of lime. The incoming pickle liquor had a pH of about 1.0, but the neutralized liquor had a pH in the range of 10. The neutralized liquor is pumped into the sludge system, which is more fully discussed in the next section.

Sludge Handling

It was previously mentioned that the sludge from the clarifier, as well as the neutralized acid sludge, would be given further consideration in this section. During early 1953, an average of 18,300 gal. per week of neutralized acid sludge was pumped to the neutralized acid storage tank and after standing for at least 12 hr. about 6,900 gal. of water was decanted from the tank. About 15,000 gal. per week of sludge was drawn from the clarifier

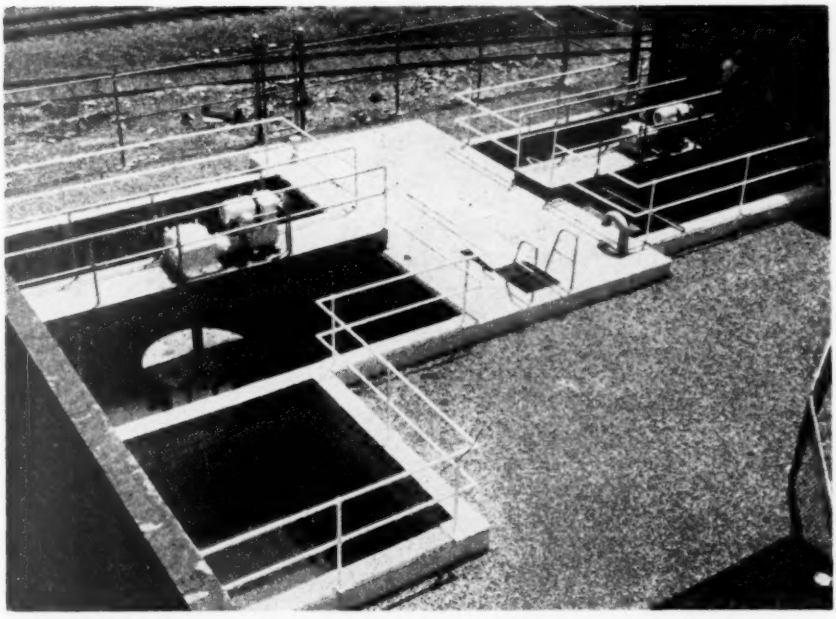

FIGURE 5.—Sludge handling system at Erie. Tank in foreground is for final storage of sludge just ahead of filtration. Neutralized acid storage tank is in left rear; blending tank for clarifier sludge and acid sludge is at right rear.

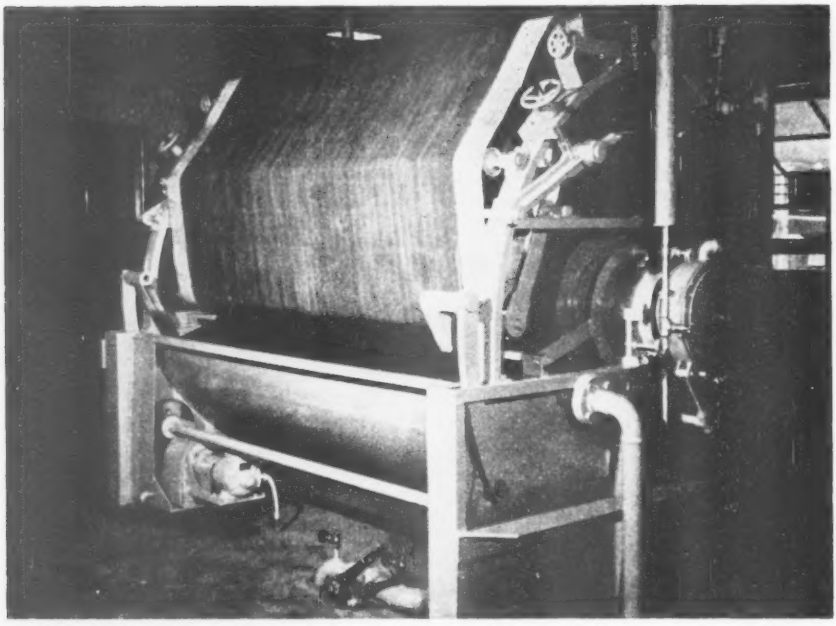

FIGURE 6.—One of the two face string, discharge type, rotary vacuum filters used in filtering sludge.

into a blending tank. In this 15,000-gal. blending tank, this clarifier sludge is blended, under agitation, with the acid sludge already mentioned. If conditions permit, water is again decanted from the sludge in the blending tank.

The conditioned sludge is then pumped to a 10,000-gal. concentrated sludge storage tank. Figure 5 shows some of the details of the sludge handling system. From the storage tank, this sludge is pumped to two 5-ft. diameter, 7-ft. long, face string, discharge type, rotary vacuum filters. Figure 6 shows some of the details of one of these filters. The sludge from these filters, located in the second story of the chemical control building, is discharged down a chute by conveyor into tote buckets to be hauled away to a dump. The filtrate from the filters flows back to the metal-bearing rinse tank.

When the plant was first placed in operation, it was felt that it would be necessary to use a filter aid to make the filters function properly. Accordingly, fly ash was used for some months. Experience finally indicated that fly ash of the type available was too abrasive for satisfactory filter aid use. Ad-

TABLE IV.—Sludge Filtration Results, 1952

Month	Conditioned Sludge to Filters (gal.)	Filtrate (gal.)	Filter Cake	
			(cu. ft.)	Solids (%)
July	76,922	53,534	3,372	39.05
August	26,696	16,680	1,378	43.00
September	15,901	9,863	955	46.75
October	31,222	19,895	1,503	41.16
November	42,534	26,383	2,144	40.42
December	59,488	31,245	2,737	41.80
Totals	252,763	157,600	12,089	—
Monthly av.	42,127	26,267	2,015	—
Daily av.*	4,861	3,031	232	42.0

* Generally, the filters are operated about 10 days per month.

ditional operating experience ultimately demonstrated that this type of sludge could be filtered without using any filter aid.

Table IV shows that 252,763 gal. of conditioned sludge was pumped to the filters during the last half of 1952. The filters thus received an average of 42,127 gal. per month. On this basis, an average of 232 cu. ft. of dewatered sludge was hauled away from the vacuum filters each operating day. This sludge had an average solids content of 42 per cent. The average daily quantity of conditioned sludge coming to the filters amounted to 4,861 gal. An average of 3,031 gal. of filtrate was discharged from the filters each day. The filters are operated on an average of about 10 days per month.

Figure 7 shows some details of the main treatment plant at Erie. The facilities for treating cyanide and chromium, as well as equipment for handling sludge, are included. The chemical control building is also quite apparent.

To confirm the fact that no objectionable wastes of consequence either leave the treatment plant or are bypassed around it, a sampling station—consisting of a weir box and recorder, an automatic sampler, and a pH meter—is planned for the final discharge ditch carrying the total plant waste to Lake Erie. Such a station is now possible, as in the over-all program of waste improvement the discharge from the three original individual sewers has been collected by an interceptor for discharge down a single ditch to the lake. All the equipment is now in use in this final discharge station except the weir box and recorder. Installation of these items should be completed soon. Table V shows that condition of the final plant effluent leaving the plant.

Installation and Operating Costs

The installation cost of the waste treatment plant at Erie has been summarized in Table VI. This table shows that the complete system cost $705,472.

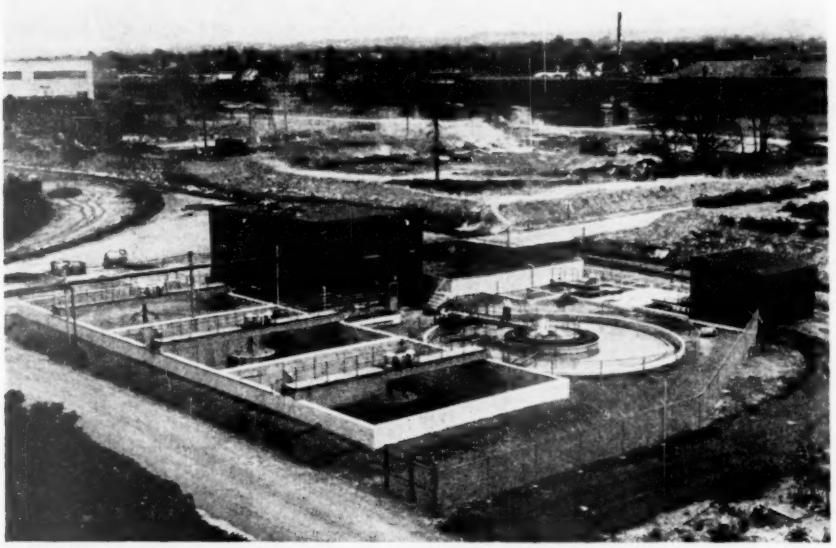

FIGURE 7.—Wastes treatment plant, General Electric Company, Erie, Pa. Units are, left to right: Three batch tanks for cyanide oxidation, chemical control building, clarifier tank, metal-bearing wastes tanks, and sludge conditioning tanks.

TABLE V.—Condition of Final Effluent Leaving the Erie Plant, General Electric Co., Early 1953*

Month	pH	Cu (p.p.m.)	Cr (p.p.m.)	Al (p.p.m.)	CN (p.p.m.)	Fe (p.p.m.)	Zn (p.p.m.)	Cd (p.p.m.)
February:								
Max.	7.6	1.0	1.9	1.8	0	1.3	0	0
Min.	7.4	0.02	0	0.09	0	0.20	0	0
Av.	—	0.15	0.28	0.72	0	0.70	0	0
March:								
Max.	7.6	1.0	0.3	0.3	0	1.6	0	0
Min.	7.4	0.02	0	0	0	0.3	0	0
Av.	—	0.15	0.09	0.10	0	0.80	0	0
April:								
Max.	7.7	1.2	0.4	0.3	0	1.9	0	0
Min.	7.3	0	0.02	0.09	0	0.09	0	0
Av.	—	0.19	0.22	0.16	0	0.74	0	0

* Analytical results based on daily analyses for the months under consideration.

The collection systems cost $242,927, or 34.4 per cent of the cost of the complete system. Table VI further indicates that the treatment system for metal rinse waters had a cost of $369,706, or 52 per cent of the total cost of the complete system. It can further be observed from the table that the spent acid neutralization system is the least costly of the three systems in question, having a total cost of $133,935, which amounts to 19 per cent of the cost of the complete system.

The cost of the collection system in this plant bears out the fact that a sizable portion of the cost of the treatment system in a large and complex plant is in the facilities necessary to collect the wastes for treatment. Since plants vary widely in size and character, the 34.4 per cent of the total construction cost of industrial waste facilities spent at Erie for the collection system would not necessarily be representative of conditions to be found elsewhere. Collection system costs for new plants are generally lower than those for existing plants.

The costs of operating the waste treatment plant in Erie for the year 1952 are summarized in Table VII, which shows that the treatment costs were $32,556 and the total costs, including depreciation, amounted to $102,023. The estimates in the cost breakdown are based on the intimate familiarity of operating personnel with the costs for treating each type of waste. After depreciation and other fixed costs are factored into the pic-

TABLE VI.—Estimated Installation Costs, Waste Treatment System, Erie (Pa.) Plant, General Electric Co.

Waste	Costs				Prop. of Total Cost	
	Treat. Fac.	Coll. Lines	Total System		Treat. Fac.	Coll. System
	($)	($)	($)	(%)	(%)	(%)
Metal rinse waters	196,821	172,885	369,706	52	53.3	46.7
Cyanides	159,337	42,494	201,831	29	78.9	21.1
Spent acids	106,387	27,548	133,935	19	79.4	20.6
Total	462,545*	242,927*	705,472*	100	65.6	34.4

* Actual contract expenditures.

TABLE VII.—1952 Operating Costs, Waste Treatment Plant

Item	Operating Cost ($)			
	Metal Rinse Waters	Cyanides	Spent Acids	Total
(*a*) Operating Expenses				
Chemicals	$ 4,012	$ 1,004	$ 1,671	$ 6,687*
Superv., labor, maint., and all others	12,145	3,039	5,056	20,240*
Utilities	1,638	407	681	2,726*
Miscellaneous	1,742	435	726	2,903*
Sub-total	19,537	4,885	8,134	32,556*
(*b*) Fixed Expenses				
Depreciation	26,745	21,855	10,309	58,909*
Taxes and others	4,793	3,917	1,848	10,558*
Sub-total	31,538	25,772	12,157	69,467*
(*c*) Total Expenses				
Grand total	51,075	30,657	20,291	102,023*

* Actual costs.

ture, it can be seen that the metal rinse water costs amounted to approximately 50 per cent of the annual operating cost and the cyanides and spent acids accounted for about 29.4 and 19.6 per cent, respectively, of this operating cost.

Table VIII has been developed to relate the cost of treatment to the quantity of wastes passing through the treatment plant. This table shows that the treatment plant alone had an installation cost of $0.96 per gallon per day of wastes requiring treatment. If the collection system is totaled with the treatment plant cost, this figure becomes $1.45 per gallon per day of wastes requiring treatment. The treatment plant installation cost for the various types of wastes ranges between $0.74 for metal rinses and $7.75 for spent acids per gallon per day of wastes requiring treatment.

If the costs of treating spent acids are expressed on the per gallon basis, the treatment costs become $0.026

TABLE VIII.—Costs per Unit Volume for Waste Treatment Plant Installation and Operation

Waste	Instal. Cost ($)	Quan. Treated*		Treat. Pl. Oper. Cost* ($)		Instal. Cost ($/g.p.d.)	Treat. Cost ($/1,000 gal.)	
		Av. (g.p.d.)	Total (m.g.)	Incl. Depr.	Excl. Depr.		Incl. Depr.	Excl. Depr.
Metal rinse waters	196,821	266,115	31.493	51,075	19,537	0.74	1.62	0.62
Cyanides	159,337	32,000	4.000	30,657	4,885	5.00	7.67	1.22
Spent acids	106,387	13,696	0.310	20,291	8,134	7.75	65.50	26.20
Total	462,545	479,811	35.803	102,023	32,556	0.96	2.85	0.91

* Last half of 1952.

per gallon, and when depreciation is included this figure increases to $0.065 per gallon. The composite waste had a treatment cost of $0.91 per 1,000 gal., the inclusion of depreciation increasing this figure to $2.85 per 1,000 gal.

As would be expected, the cost of the treatment plant per volume of each waste handled varies widely in a manner somewhat related to the volume of each of the wastes in question. On the basis of installation costs per gallon per day of wastes requiring treatment, the spent acids with the low daily volume of 13,696 gal. had the high installation cost of $7.75. At the other end of the scale the metal rinse waters, with the considerable daily volume of 266,115 gal., had an installation cost of $0.74 per gallon per day. The cyanide rinse waters, with a daily volume of 32,000 gal., falls between the two limits listed, with a treatment plant installation cost of $5.00 per gallon per day. This $5.00 cost figure is occasioned primarily by the batch treatment facilities provided for cyanide treatment. Continuous treatment facilities for the same quantity of cyanide rinse water should result in an installation cost on the gallon volume basis approaching that for the metal rinse waters.

Treatment costs also vary with the volume of the various types of wastes in question. Table VIII demonstrates that the wastes vary in treatment costs per 1,000 gallons as follows: metal rinse waters, $0.62; cyanide rinses, $1.22; and spent acid, $26.20. Acid treatment costs are high because the acid is comparatively concentrated and considerable lime is required for neutralization. Cyanide treatment costs are higher than metal rinse-water costs because the cyanide concentrations are higher in one case than is the chromium in the other and the chlorine required for oxidizing the cyanide adds to the cost of this operation.

This discussion of treatment costs bears out the fact that waste treatment is expensive. This summary of cost figures is another clear indication, therefore, that a waste problem should be reduced by steps short of treatment and it should further be cut in volume by diverting all clean water before "last-resort" waste treatment is undertaken.

Summary and Conclusions

As a result of being able to look in retrospect at a period of almost 6 years since waste treatment was first seriously considered at Erie and a period of 2½ years of actual waste treatment experience, some rather significant conclusions can be drawn, as follows:

1. The industrial waste treatment plant at the Erie works during its 2½ years of operation has treated metal-finishing wastes carrying acids, cyanides, chromium, and other metal ions in such a manner and to such a degree as to discharge a satisfactory effluent into Lake Erie. Familiarity with operations contemplated at Erie for the future indicates that this plant should continue to do a completely satisfactory job for a long time to come.

2. Industrial waste treatment at Erie is expensive, as the plant had an installation cost, including the collection system, of $705,000, and its operating cost runs approximately $100,000 per year. The collection system costs at Erie, which are not necessarily representative of those to be expected elsewhere amounted to $242,927. Treatment systems, and in particular collection systems, are generally lower in cost if the treatment facilities can be designed and built as an integral part of a new plant.

3. The cost of waste treatment facilities and their operation constitutes one of the major reasons why industrial plants should first simplify and reduce an industrial waste problem by the soundest and most economical steps available consisting of within-the-plant,

short-of-treatment efforts, before going to "last-resort" treatment.

4. Experience at Erie and elsewhere in the waste treatment field indicates that industrial, consulting engineering, and regulatory agency representatives in developing the degree to which industrial wastes must be treated should thoroughly consider all the equities involved, to the end that these aggregate efforts will result in a properly sized, minimum cost treatment plant. The installation of larger-than-necessary treatment facilities means higher manufacturing costs, which will ultimately be reflected in the end cost of the product to the consumer.

5. The acid and cyanide treatment facilities at Erie are somewhat large for present operations. This fact is true for the following reasons:

(a) There is one point that all major industrial plants must face in constructing waste treatment facilities. Most plants should be designed to take care of operations for the foreseeable future. That was the type of plant envisioned and constructed for the Erie works, but unforeseeable process changes have taken place and in this case reduced the waste load. It is also conceivable that on a similar basis a plant could have an unforeseen change of process which would increase the waste load. Still another major process change is projected for Erie which will have a major effect on the waste load. This has been the history at the Erie works and it is probably representative of that to be expected at other large plants.

(b) Company personnel proposed the installation of facilities for the continuous treatment of cyanides at the Erie works. The batch treatment method of handling cyanides being used was provided to comply with the requirements of the state having jurisdiction. The historic record of operating experience in recent years at a number of plants which are continuously treating cyanide wastes probably substantiates the position that such continuous treatment would have proved satisfactory at Erie. The apparent desirability of batch treatment then, compared to the practicability of continuous treatment now, can no doubt be partly attributed to the advances in the treatment art in the intervening 6-year period.

6. The comparatively new method of dewatering industrial waste sludges by vacuum filtration to make them easy to handle has been found highly satisfactory at the Erie plant. This work has proved beyond question that a mixture of clarifier and neutralized acid sludge similar to that produced at Erie can readily be filtered on a continuous basis without the use of a filter aid. This method of handling sludge is more costly than lagooning, but subsurface conditions made lagooning difficult at this plant. Further, as a result of operating experience it is the feeling of Erie personnel that the added convenience in handling the filtered sludge is well worth the difference in cost. The type of original thinking given sludge handling by Erie plant, consulting engineering, and equipment manufacturing personnel is representative of that which should be encouraged in the waste treatment field.

7. Work at Erie indicated that fly ash of the type available there is too abrasive to serve satisfactorily as a filter aid for the filtration of sludge as practiced at that plant.

8. The somewhat unusual collection system in use at Erie has worked quite effectively and demonstrates that wastes can be segregated and conveyed out of manufacturing buildings to the

treatment plant by the use of pumps and overhead lines.

9. The separation of the pickle liquor neutralization facilities some distance from the main treatment plant at Erie, is not necessarily considered to be the best practice in designing such facilities. This particular separation at Erie was used to permit advantage to be taken of tank capacity already available for the neutralization of acids.

Acknowledgments

Particular appreciation is expressed to A. Divell, operator of the industrial waste treatment plant at the Erie works, who contributed much of the background data used in this paper. His intimate knowledge of the various wastes and their treatment was an invaluable source of information in attempting to summarize the treatment story at Erie.

Appreciation is also expressed to W. C. Breter of the Building, Grounds, and Power Group for his suggestions in preparing the paper. Appreciation also is due H. R. Brown and L. E. Baldridge of the financial sub-section at Erie for their comprehensive counsel and aid on matters of an accounting nature covered in this paper.

DISCUSSION

By William S. Wise

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To those engaged in the field of pollution control this paper is unusually interesting and valuable. Besides presenting, in considerable detail, the construction and operating costs of the treatment facilities—a much-needed and long-needed contribution to the industrial waste treatment field—the paper demonstrates a feasible method of separating those wastes needing treatment from those which do not, and then separating the different kinds of wastes for better treatment control —all achieved in a large plant, not of recent construction. Another interesting point is that the waste treatment program was initiated by the company without pressure from the state pollution control agency—a laudable policy. In addition, the company, for its apparent sincerity in doing the job well to eliminate any adverse conditions in Lake Erie—to the extent of a $705,000 constructive expenditure and a $100,000 per year operating cost—deserves a generous commendation and appropriate recognition.

Too frequently some industrial concerns, faced with an expensive treatment problem, defer attacking it until forced to take action; then, inadvertently complicating it by trying to determine the minimum that can be done to get by. Too frequently it is assumed that the wastes cannot be separated and collected because of the great difficulty and expense in laying new drains under heavy concrete floors and under heavy machinery. Too frequently it is claimed that the costs are not commensurate with the benefits. Rarely are concerns interested in analyzing the costs and benefits and making such information available to the public. This paper clearly demonstrates the old adage, "Where there is a will there is a way."

The sizable cost involved at the Erie plant naturally excites interest and curiosity in the various features of the plant and the problem. In the light of experiences in Connecticut, an item which attracts attention is the one involving cyanide treatment. It is noted that batch treatment was adopted at the request of the state pollution con-

trol agency in contrast to continuous treatment proposed by the company. The report shows that the average cyanide concentration is about 30 p.p.m. and the construction cost for this treatment was $5.00 per gallon per day of wastes treated. The operating costs amount to $1.22 per 1,000 gal. of wastes without depreciation, and $7.67 including depreciation. The report does not indicate special conditions or considerations which may have influenced the decision relative to the method of treatment.

It is interesting to note that about six years ago a plant was proposed and approved in Connecticut for the continuous chlorination of cyanide-bearing wastes. The plant was designed to handle 60,000 g.p.d. and its construction cost was approximately $60,000. The wastes have a cyanide concentration similar to those at Erie and the operating costs are about $0.55 per 1,000 gal., including the precipitation of metals and sludge disposal on drying beds. The effluent is discharged into a river and the results have always been good. About the same time another plant in the state was approved for batch treatment of spent strong cyanide wastes and spent acid wastes. The concentration of these wastes are many thousands p.p.m. and the cost figures are not readily available, but they are very much higher, on a comparative basis, than those last noted above.

In 1939 the first plating waste treatment plant was built in Connecticut at the Electrolux plant in Greenwich. Batch treatment was adopted for the precipitation of metals and the reduction of cyanide concentration. At that time chlorination of cyanide wastes had not been developed and it was not the principal problem. The plant consists of eight 20,000-gal. wooden tanks with agitators, pumps, and a small operating building. The sludge is allowed to accumulate in each tank for a number of treatments and is then disposed of by hauling it in a tank truck to a municipal disposal area. Hexavalent chromium is reduced by sodium metabisulfite after pH reduction by sulfuric acid to between 2.0 and 3.0. Lime is used for neutralization and precipitation. The plant as first built contained two tanks, two more being added in 1945, and four more in 1947. The construction cost has been approximately $30,000 and the cost of treating an average of 225,000 gal. per 16-hr. day is $0.35 per 1,000 gal., exclusive of depreciation. The cost is divided almost equally between chemicals and labor.

In 1951 another plant was constructed in Connecticut for the continuous treatment of plating room wastes, including chlorination of cyanides. In this case the treatment plant was designed and built simultaneously with the manufacturing plant—the Hamilton Standard Propeller Division, United Aircraft Corp., at Windsor Locks. All kinds of plating operations are carried out here, except that chromium is comparatively small. The plant was designed to treat 400 g.p.m. and is presently handling about 325 g.p.m. This plant consists of a two-story operating building, a circular mechanical clarifier, and a sludge drying bed. The first floor of the operating building contains the chlorination facilities and the lower portions of three storage tanks, for batch treatment of spent acids. The second floor contains the lime feeders and chemical solution tanks. The construction cost of the treatment plant was approximately $165,000 and the operating costs, exclusive of depreciation, amount to about $0.17 per 1,000 gal. The plant operates 24 hr. per day, with full time supervision during the day and part time supervision during the night, when the character of the wastes is more uniform. Automatic controls are provided.

The data showing the construction and operating costs in Connecticut are,

of course, not presented to convey the impression that waste treatment in that state is much less costly than it is elsewhere. The figures are obviously not directly comparable because the character and volumes of wastes, certain features of the treatment processes and treatment requirements, variable conditions affecting plant layout with respect to manufacturing plant facilities, and other factors govern the costs of such installations. Problems of this type are not amenable to "handbook" solutions, but each represents an individual problem and calls for an individual solution.

The successful use of vacuum filtration for dewatering sludge at Erie is most encouraging. When the Electrolux plant was built in 1939 a filter press was installed for sludge dewatering. The difficulties encountered in operation were so great that it was abandoned after the first year in favor of trucking away the liquid sludge. In 1947 a small pilot-plant installation, on brass mill wastes, demonstrated that such sludges could be practically and successfully dewatered on vacuum filters without a filter aid. The Erie installation and experience shows that although this method of sludge handling may be somewhat more costly, it does provide a method of processing such sludges where other methods are not available.

Mr. Watson's summary and conclusions are sound and most opportune. The field of treating metal-finishing wastes is large, and the developments in treatment processes have not emerged very far above the infancy stage. The conclusions are helpful and useful to the industrialist faced with such problems, to the consulting engineer engaged in the design of such works, and to representatives of pollution control agencies whose duties call for the promotion of pollution abatement measures. The General Electric Company should be congratulated for the spirit in which the problem was undertaken and the corrective measures were applied.

CONTRACT AWARDS, SECOND AND THIRD QUARTERS, 1953

During the second quarter of 1953, municipalities awarded contracts for 204 projects to abate water pollution and conserve water resources, according to the U. S. Public Health Service. The $64,600,000 represented by these public sewage treatment plant projects was more than double the amount for the first quarter's contracts, and 55 per cent greater than that reported in the corresponding 1952 period. Of the 204 projects, 118 were for new plants, costing $45,300,000, and 86 were additions, enlargements, or replacements, costing $19,300,000.

During the third quarter, according to the same source, construction contracts were awarded for an additional 155 projects. The contracts totaled $38,000,000 and covered 87 new plants and 68 additions, enlargements, or improvements to existing plants. Of the 87 new plants, costing $24,600,000, only 7 were for places of more than 20,000 population, although these 7 plants accounted for 60 per cent of the total new plant cost. More than half of the new plants were to serve places of fewer than 5,000 population. Although both the number and dollar value of the contracts for the third quarter were substantially below those for the previous quarter, the totals for the first nine months of 1953 were still about 20 per cent higher than for the comparable period of 1952.

CHROMIC ACID RECOVERY BY ION EXCHANGE*

By R. J. Brink

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Reasons for Installation

Before giving details on the operation of the chromic acid recovery system at the Buick Motor Division of General Motors Corp., it is felt that some reasons for installing this system are in order. With the advent of defense work, Buick was faced with the problem of disposing of anodizing rinse water containing an estimated 100 p.p.m. of CrO_3. At that time there were no disposal facilities. The problem was considered from both the disposal angle and the possibility of a recovery system. It was estimated that a disposal plant and equipment would cost about $60,000 installed. A system of chrome recovery was quoted at $30,000, with installation of this equipment estimated at $10,000. The decision was made to install the ion exchange recovery system.

After working with several manufacturers of this type of equipment, that of the Illinois Water Treatment Company was selected. It was felt that the safest approach to the recovery of chromic acid was to first convert it to sodium chromate before it entered the ion exchanger, the same system also advocated by this company.

Description

The chrome recovery equipment (see Figure 1) consists of one 48-in. by 48-in. by 48-in. neutralization tank, in which caustic is added to neutralize the chromic acid rinse water to a pH of 8.4, forming sodium chromate. The pH control is maintained by a pH indicating recorder with multiple electrode leads. The sodium chromate solution is pumped through a 36-in. diameter by 96-in. anion tank and then through a 30-in. diameter by 84-in. cation tank. The effluent from the anion exchanger contains only sodium hydroxide, the chromate ion remaining in the anion exchanger. The cation exchanger, in turn, removes the sodium ion leaving deionized water to return to the rinsing tank.

The regenerate effluent from the anion exchanger contains sodium chromate, which is collected in a 42-in. by 60-in. by 48-in. tank. This sodium chromate is then pumped through a 48-in. diameter by 84-in. cation exchanger, which converts the sodium chromate to chromic acid and removes any contaminating cations. The purified chromic acid can be returned to the anodizing tanks.

The system includes two circulating pumps (one for stand-by) for the neutralization tank. It also includes two sodium chromate solution pumps, which transfer the solution through the ion exchangers. The system contains one Duriron pump for transfer of acid solutions.

The ion exchange unit is a duplex unit, where one unit is on stand-by duty. This unit requires soft, or deionized, water for operation. All valves are numbered and lettered A or B (see Figure 2) according to unit.

Each anion and cation unit is designed to provide 24-hr. operation per regeneration when treating rinse water at the rate of 2,000 g.p.h. with water

* Presented at 1953 Annual Meeting, Michigan Sewage and Industrial Wastes Assn.; East Lansing, Mich.; Sept. 21–23, 1953.

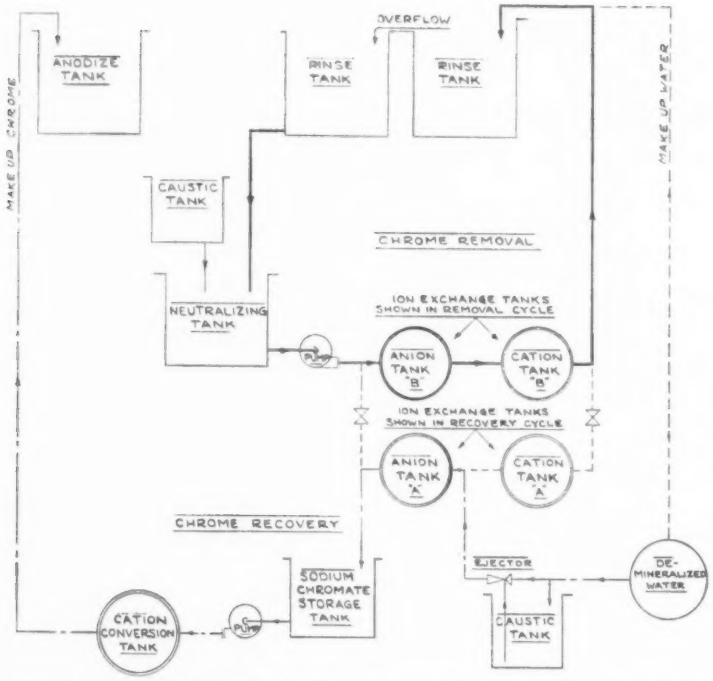

FIGURE 1.—Flow diagram for chrome recovery by ion exchange method.

containing 1.00 g. per liter of chromic acid, or approximately 40 lb. of chromic acid.

Equipment and Resins Used

The equipment involved in this recovery process is outlined in Table I. Detailed operating instructions are posted at key points, including value identification diagrams such as Figure 2.

The anion resin* is Illco A–244 (strongly basic), with a designed capacity of 12,000 grains of chromate ion (as $CaCO_3$ equivalent) per cubic foot of resin. Each anion unit contains 24 cu. ft. of resin and requires approximately 850 gal. of water for a regeneration cycle. The unit was designed with a capacity of 40 lb. of CrO_3, but actual operation has shown that it can hold up to 60 lb. The flow rate is based on 2,000 g.p.h. for a total of 48,000 gal. of rinse water.

The cation resin is Illco C–271, which is a carboxylic-type resin with a designed capacity of 24,000 grains (as $CaCO_3$) per cubic foot. Here, too, the flow rate is based on 2,000 g.p.h. with a capacity of 48,000 gal. total. Each cation unit contains 12.5 cu. ft. of resin and requires approximately 1,200 gal. of water for a regeneration cycle. The cation resin in the conversion unit (converts the recovered sodium cromates back to chromic acid) is Illco C–211 (a sulfonated styrene-base resin). This unit is designed to treat the solution from one regeneration of an anion exchange unit, but in actual practice its capacity has been found to be much higher. The cation conversion unit contains 40 cu. ft. of resin and requires approximately 3,500 gal. of water for a regeneration cycle.

* All resins were supplied by Rohm and Haas Co., Philadelphia, Pa.

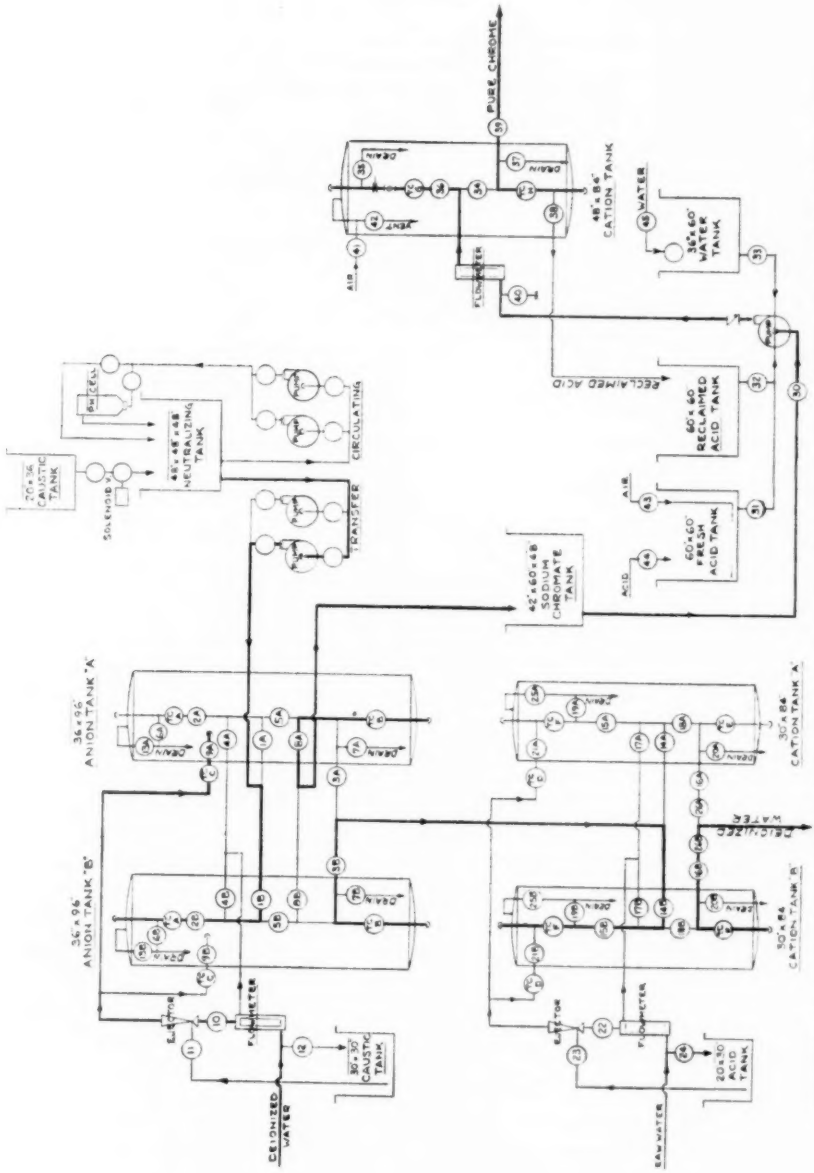

FIGURE 2.—Valve identification chart used in instructions for operation of chrome recovery from rinse water.

TABLE I. Equipment Used in Chrome Recovery by Ion Exchange Method, Buick Motor Division, General Motors Corp.

Type	No.	Size	Remarks
Caustic tank	1	20-in. dia. by 36 in. deep; 48 gal.	
Neutralization tank	1	48 in. square by 48 in. deep; 480 gal.	
Anion tank	2	36-in. dia. by 96 in.	Incl. exchange resins
Cation tank	2	30-in. dia. by 84 in.	Incl. exchange resins
Sodium chromate tank	1	42 in. by 60 in. by 48 in. deep; 525 gal.	
Cation exchanger	1	48-in. dia. by 84 in.	Incl. exchange resins
Circulating pump	2	50 g.p.m. at 5-ft. head	
Transfer pump	2	40 g.p.m. at 50-ft. head	
Acid transfer pump	1	—	Duriron
Recording pH meter	1	—	Operates solenoid valve
Conductivity controller	2	0.1 to 100 grain per gal.	
Conductivity controller	2	0.1 to 300 grain per gal.	
Motorized valves	4	1½ in. opening	
Caustic solution tank	1	30-in. dia. by 30 in. deep; 90 gal.	Anion regeneration
Sulfuric acid tank	1	40 gal.	Lead lined, cation regen.
Sulfuric fresh acid tank	1	1,220 gal.	Lead lined, cation regen.
Sulfuric reclaim acid tank	1	1,220 gal.	Lead lined, cation regen.

Operating Data

Table II gives some operating data. Disposal costs have been added merely for comparison. In connection with Table II, it should be noted that during the operating period covered, a total of 292 lb. of NaOH was used in the neutralizing tank ahead of the anion units, at an additional cost of $12.41.

On the basis of seven batches run during a period of seven months under limited operating conditions, the value of CrO_3 and water saved per run amounted to $15.40, whereas the cost to reclaim, including the cost of the NaOH used in the neutralizing tank,

TABLE II.—Operating Data, Chrome Recovery by Ion Exchange

Unit	Batch No.	CrO_3 Recovered (lb.)		Req. for Regeneration[2]			Value of CrO_3 Recovered[3] ($)	Cost of Recovery Materials[4] ($)	Water Saved by Recovery (gal.)	Value of Water and CrO_3 Saved ($)	Cost if CrO_3 Destroyed Rather than Recovered[5] ($)
		Anion Unit[1]	Cation Unit	NaOH (lb.)	H_2SO_4 (lb.)	Water (gal.)					
B	1	28.6	22.94	120	—	850	6.88	5.20	48,000	12.16	9.26[6]
B	2	78.0	31.0	120	600	4,350	9.30	13.50	48,000	14.58	24.17[6]
A	1	83.7	21.2	120	600	4,350	6.36	13.50	48,000	11.64	26.04
B	3	33.8	16.55	120	600	4,350	4.97	13.50	48,000	9.25	10.92[6]
A	2	44.3	35.3	120	44	2,050	10.59	5.85	48,000	15.87	12.60[6]
B	4	49.2	49.3	120	644	5,550	14.79	14.21	48,000	20.07	14.80
A	3	48.6	45.6	120	44	2,050	13.68	5.85	48,000	18.96	15.62[6]
B	5	54.4	51.3	120	644	5,550	15.39	14.21	48,000	20.67	16.10

[1] As Na_2CrO_4.

[2] 600 lb. of H_2SO_4 is required for regeneration of cation conversion unit; 44 lb., for regeneration of cation unit used for removal of Na ion. Regeneration not required after every cycle of the anion unit, as cation units have greater capacity.

[3] CrO_3 at $0.30 per pound.

[4] H_2SO_4 at $0.0133 per pound; NaOH at $0.042 per pound; water at $0.11 per 1,000 gal.

[5] $NaHSO_3$ at 3 lb. per pound of CrO_3; $NaHSO_3$ at $0.084 per pound; H_2SO_4 at $0.0133 per pound.

[6] Actual costs; the CrO_3 was destroyed for data purposes.

averaged $12.28. The net gain on recovery, therefore, was $3.12 per batch. However, if the cost of disposing of the CrO_3 from the rinse water is considered (this item average $16.19 per batch), the total saving averaged $19.31 per batch.

It was found in actual operation that advantage could be taken of the fact that there are four anodizing tanks in this line, each containing 2,000 gal. of solution and each having a large surface area. As a result, more of the eluted sodium chromate, and correspondingly more of the chromic acid, can be recovered. Although the recovered solutions are lower in concentration, the loss by evaporation in the anodizing baths compensates for the difference. Advantage can also be taken of the final portion of the recovery backwash from the anion unit when the concentration of sodium chromate is very low but the alkalinity is very high. This solution can be stored and used in the neutralizing tank to supplement the regular additions of caustic soda. A point to be made is that the neutralizing tank should be large enough to accommodate this dilute solution.

Two-Fold Use of Cation Conversion Unit

The cation conversion unit has another use in addition to the recovery of CrO_3. The second function is the removal of the aluminum from the anodizing bath. When the aluminum in the anodizing bath builds up to a concentration of 0.75 to 1 g. per liter, experience has shown that trouble may be encountered in attempting to meet a 250-hr. salt spray requirement. The aim at this plant is to hold the aluminum concentration below 0.5 g. per liter.

There are four anodizing tanks involved in this operation, each with a capacity of 2,000 gal. The CrO_3 concentration is maintained at 8 oz. per gallon. The aluminum increases in each tank at the average rate of 0.13 g. per liter per week. To maintain a concentration of aluminum below 0.5 g. per liter, it is necessary to cycle one of these 2,000-gal. tanks through the cation conversion unit each week. By this use of ion exchange, rather than dumping and destroying a portion of each tank each week, a total savings of $268.66 per week is being realized (see Table III).

TABLE III.—Operating Data for Removal of Aluminum by Ion Exchange* and Destruction of Anodizing Bath

(a) Aluminum removal by ion exchange	
Al content (g/l.):	
Prior to ion exch.	0.47
After ion exch.	0.13
CrO_3 conc. (oz./gal.):	
Prior to ion exch.	8.48
After ion exch.	7.46
CrO_3 req. to bring bath to strength (lb.)	100
Cost of each ion exch. cycle:	
CrO_3 (100 lb. @ $0.30)	$30.00
H_2SO_4 (600 lb. @ $0.0133)	7.98
Water (2,500 gal. @ $0.11/1,000 gal.)	0.28
Total	$38.26
(b) Destruction of part of anodizing bath	
Cost to destroy 1,000 gal. of solution at 8 oz. CrO_3 per gallon:	
$NaHSO_3$ (1,560 lb. @ $0.084)	$131.04
NaOH (600 lb. @ $0.0425)	25.50
H_2SO_4 (20 lb. @ $0.0133)	0.27
Water (1,000 gal. @ $0.11/1,000 gal.)	0.11
CrO_3 repl. (500 lb. @ $0.30)	150.00
Total	$306.92
(c) Total savings, per week	$268.66

* Averages of 8-months operating data.

Trouble with Chlorides

Although deionized water was employed throughout this system, chlorides were appearing in the anodizing bath. Chlorides are another factor that may cause a decrease in salt spray resistance of the anodized coating. The source of chlorides was traced to the caustic soda used in the neutralizing

tank and in the recovery of the sodium chromate. Nylon-grade caustic, which is free of chlorides, is being used for the purpose.

Conclusions

When chrome from the rinse tanks is considered alone, and water conservation is no problem, consideration should be given to disposal if any facilities are available. If a disposal plant and water saving must be considered, then ion exchange definitely has its place.

When the removal of aluminum from an anodizing bath by ion exchange is compared to dumping and disposing of portions of the bath, ion exchange is warranted and can show considerable saving.

WICHITA, KANSAS, TUNNELS SMALL SEWER

Growth of Wichita, Kans., recently forced installation of additional sewer facilities to handle the increased flow. Although the original (1933) 24-in. sub-main line was still in excellent condition, its capacity was inadequate. The new line roughly parallels the old one.

An interesting part of the job involved approximately 1,060 ft. of 15-in. vitrified clay pipe, which was tunneled through a ridge in the northeastern part of the city at a depth of 30 to 33 ft. below ground level. Ground conditions in the completely developed residential section would have made regular trenching methods difficult and costly.

Shafts 10 ft. by 12 ft. in plan were spaced at 100- to 200-ft. intervals. A tunnel 3 ft. wide and 5 ft. high was then cut between the shafts. As the face advanced, the tunnel was lined along the top and sides with 3-in. by 12-in. planks (Figure 1).

The pipe was installed in the tunnel on cradles, jointed, and then the entire tunnel was filled with concrete. The tunnel section was only a small portion of the entire job, which called for 4.8 mi. of pipe.

FIGURE 1.—Deep sewer in residential district of Wichita, Kans., was installed in 3-ft. by 5-ft. sheeted tunnel later solidly backfilled with concrete.

Stream Pollution

DETERMINING RISKS OF TOXIC SUBSTANCES IN WATER *

By Edward J. Cleary

Executive Director and Chief Engineer, Ohio River Valley Water Sanitation Commission, Cincinnati, Ohio

What toxic effects to man and animals may result from continued consumption of water contaminated with industrial wastes? Or from end-products of organic decomposition? Or from treatment of certain raw water supplies by chemical means?

These are questions that cannot be ignored by those conerned with water quality. These questions have special meaning to the Ohio River Valley Water Sanitation Commission, dealing as it must with the establishment of industrial waste control measures.

Workers in the field of sanitation relating to water supply and waste disposal have been peculiarly unresponsive to problems of toxicity. From the standpoint of water quality, principal attention has been focused on bacteriological hazards. Certainly there has been no organized program of investigations to determine if unsuspected public health hazards may exist as a result of trace constituents from industrial and other wastes that might find their way into watercourses.

Considering the careful study given to potential toxicity of constituents in food and drug preparations, it seems inconsistent to have ignored substances in water, which is a universal food. It appears, in fact, that much more attention has been devoted to the toxic effects of chemical wastes on fish than on humans.

It is curious, too, that many of the state laws relating to pollution control can be so positive—in a negative fashion—in the use of statements such as: "No toxic substances shall be permitted to be discharged into a stream." The implications of such a rule may be overawing; there should be a feeling of distress at the inability to apply it.

The implication, of course, is that the drafters of the rule and the administrators—not to mention those who are subject to it—possess some reliable knowledge on what substances in water are toxic. The fact is that only the most meager information is available as to what might be toxic to man or animals. And there is virtually no information as to the concentration levels at which a substance continually ingested may affect degenerative diseases, shorten life, or simply disturb one's sense of well-being.

The Ohio River Valley Water Sanitation Commission, representing eight states engaged in a regional program of pollution control, concluded that such information is vital in the conduct of its program. It is essential from the standpoint of establishing regulations. Also, it is recognized by the Commission that industries in the district require facts on toxicity for the ultimate perfection of their waste treatment measures.

The Commission then backed up its beliefs by authorizing action. That action was manifested in a contract with the University of Cincinnati for the services of The Kettering Laboratory in the Department of Preventive Medicine and Industrial Health, of the College of Medicine, to undertake the

* Presented at 26th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Miami, Fla.; Oct. 13–16, 1953.

toxicity evaluation of water pollutants. Work has been going forward on this program for some three years.

The activities of The Kettering Laboratory for a quarter of a century have been devoted principally to industrial health problems. It is staffed by medical men and specialists who are concerned primarily with health problems resulting from exposures to toxicological hazards in an industrial environment.

Scope of Project

Broadly stated, the ORSANCO toxicity project at Kettering has the following purposes:

1. To evaluate critically the currently available data on the acute and chronic toxicity for man and animals of known chemical pollutants of the waters of the eight states signatory to the Ohio River Valley compact.

2. To ascertain for which pollutants adequate data are lacking and aid in developing means for the acquisition of such data to the end that recommendations as to tolerances may be made on a well-grounded factual basis.

More specifically, program activities fall into the following categories:

1. To compile and evaluate all existing information on toxicity from which recommendations could be made to the Commission on tentative maximum allowable limits of potentially toxic substances.

2. To consult with and advise the Commission, its signatory states, and its industry committees on matters relating to the toxicity of chemical substances that might find their way into sewers and watercourses.

3. To prepare information that will reveal what industrial waste substances, in order of importance, may create potentially toxic hazards.

4. To recommend additional toxicity studies on pollutants that should be undertaken and indicate the priority of attention.

5. To cooperate with industry committees of the Commission in summarizing all information pertinent to their toxicity problems.

6. To suggest new methods and aid in the improvement of existing analytical methods for pollutants that will serve the needs of those who are concerned with effluent discharges, stream-quality determinations, or biological investigations.

7. To propose the direction of further investigations into the nature of toxic effects of pollutants on man and animals, both in the laboratory and on an epidemiological basis; suggest suitable laboratories or institutions wherein such work might be conducted; and consult with these organizations and promote collaboration with the ORSANCO-Kettering project.

It will be noted that the project activities invite the closest collaboration with industry committees of the Commission. These committees are made up of representatives of industries operating within the Ohio valley who are voluntarily serving as advisers to the Commission. There are seven committees established at the present time, representing the metal-finishing, steel, coal, chemical salts, oil refining, organic chemicals, and distilling industries.

At this point special tribute should be paid to the efforts of the National Cash Register Company, which, as a member of the Metal-Finishing Industry Committee, inaugurated a literature review on toxicity prior to the inception of the Kettering project. The contribution from the National Cash Register Company, which has assigned a full-time research staff member to literature surveys and abstracts continuously during the past three years, has greatly advanced the tempo of the ORSANCO program. From a bibliography of more than 3,500 references on toxicity, a total of 1,500 abstracts have been referred to The Kettering Laboratory for cataloging and evaluation.

How the Job Is Being Done

All of this leads to an explanation on how the job is being tackled. It will be appreciated that the task of locating, abstracting, and compiling in usable form the pertinent data from published sources on toxicology is enormous. It soon became obvious, based on the experiences of the Metal-Finishing Industry Committee group, that it would be justifiable to seek support from other committees.

It is gratifying to report that the ORSANCO Steel Industry Committee has shouldered a large part of the burden by assuming responsibility for chemical substances in which it has a special interest. Also, negotiations are underway whereby the Oil Refining Industry Committee hopes to provide substantial aid in its field of concern.

The manner in which these committee efforts are harnessed to the Kettering activities follows this pattern:

An industry committee makes a search to obtain information on all aspects of the problem with which it is concerned. The Kettering Laboratory supplements this effort with articles from specialized sources of toxicological literature relating to each of the pollutants within the province of the committee. A compilation is then made of all the references produced from literature searches made by the principal investigator of the project, along with those references independently supplied by the industry committees. These references, accompanied in some instances with reprints of the articles then available, are sent to the abstracter serving the committee.

In the case of pollutants of interest to more than one committee, the Kettering staff eliminates duplication and makes an effort to distribute the work equitably. The abstracter for the Metal-Finishing Industry Committee, as stated previously, is a staff member of the National Cash Register Company, whose efforts are under the supervision of L. Hibbert. For the Steel Industry Committee the abstracter is a staff team under direction of R. D. Hoak, of the Mellon Institute.

It is the duty of the abstracter to prepare a summary of each article, and enter specific toxicity data on a standardized tabulation sheet (Figure 1). After the abstracts and tabulations

CYANIDE 3

1	2					3				4		5	6	7	8
SUBSTANCE	SUBJECT					EXPOSURE				EFFECT		PATHOLOGY	METABOLISM	REF	EVAL
	No.	Species	Age	Size	Sex	Portal	ppm	mg/kg	Schedule	MLD %M MTD TD LD% ED	Signs		of Substance in Subject		
CN, as KCN	25E	Human	–	–	M; F	ig	–	4 mg	IX	–	–	–	Detox. CN→CNS Exc.: saliva	816	or
CN, in stream water with traces of Cu and Cd	2 cl	Bovine	–	–	–	ing	16.5 to 25	–	–	(ED)	L.	–	–	53	or
CN, in stream water	2 cl	Bovine	–	–	–	ing	0.3 to 4	–	–	(ED)	L.	–	–		
	2 cl	Bovine	–	–	–	ing	33	–	–	(ED)	L.	–	–		
Same with traces of Cu	~cl	Ducks	–	–	–	ing	ca 99			(ED)	L.	–	–		

FIGURE 1.—Tabulation form on which information from published material is assembled from scattered sources.

have been studied at Kettering, the data from each article are entered upon a "key-sort" punch card (Figure 2). A classification system has been developed for these cards which makes it possible to obtain in a matter of minutes from amassed data all information relating to varied aspects of toxicological significance. The cards, prepared by the abstracter, are then coded and placed in a central toxicity information file at The Kettering Laboratory, where they are available for reference by all participants. The original article or reprints returned by the abstracter are placed in a central literature file.

Perhaps the most important function of the abstracter lies in the tabulation of his findings on the standardized form. This is simply a device for presenting a digest of information by means of which rapid comparison can be made of related data from scattered sources. The information thus compiled is considered comprehensive rather than critical. It is from such tabulations that The Kettering Laboratory staff begins the task of making a critical evaluation of the toxicity potentials.

As shown in Figure 1 the tabulation provides eight major subdivisions for listing pertinent data. These include:

1. Substance tested, together with the medium in which it occurred (water, food, solvents), and any cross references.
2. Subject on which the results were observed, including the number of animals used, their species, age, size, and sex, and whether the study was experimental or clinical.
3. Exposure conditions, such as the route by which the substance entered the body.
4. Effects noted, in terms of clinical or physiological changes, and the dosage level at which they occurred.
5. Pathology in terms of gross or microscopic observations of organs affected and the degree of change.
6. Metabolism conditions as revealed by reactions, transportation, absorption, distribution, and excretion of the substance.

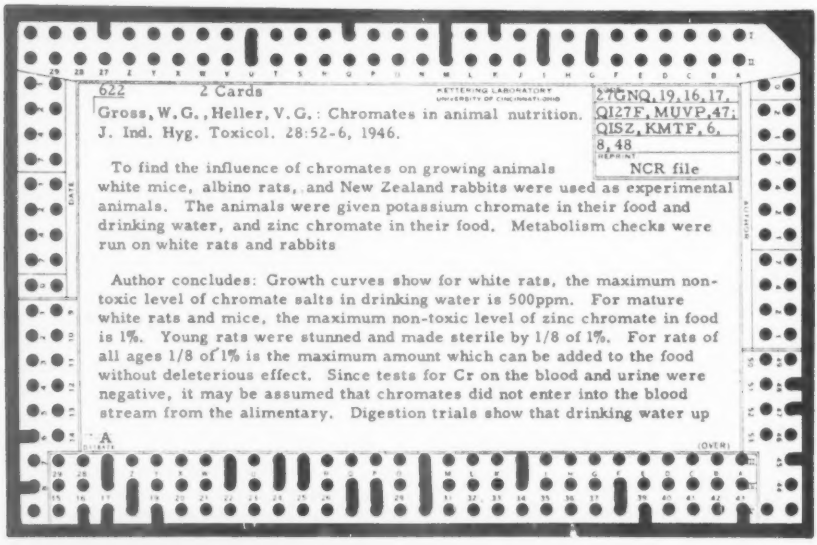
622
2 Cards
KETTERING LABORATORY
UNIVERSITY OF CINCINNATI, OHIO
27GNQ, 19, 16, 17,
QI27F, MUVP, 47;
QISZ, KMTF, 6,
8, 48
REPRINT
NCR file
Gross, W.G., Heller, V.G.: Chromates in animal nutrition.
J. Ind. Hyg. Toxicol. 28:52-6, 1946.
To find the influence of chromates on growing animals white mice, albino rats, and New Zealand rabbits were used as experimental animals. The animals were given potassium chromate in their food and drinking water, and zinc chromate in their food. Metabolism checks were run on white rats and rabbits
Author concludes: Growth curves show for white rats, the maximum non-toxic level of chromate salts in drinking water is 500ppm. For mature white rats and mice, the maximum non-toxic level of zinc chromate in food is 1%. Young rats were stunned and made sterile by 1/8 of 1%. For rats of all ages 1/8 of 1% is the maximum amount which can be added to the food without deleterious effect. Since tests for Cr on the blood and urine were negative, it may be assumed that chromates did not enter into the blood stream from the alimentary. Digestion trials show that drinking water up
A
(OVER)

FIGURE 2.—Abstracts of articles are entered on "key-sort" cards, which are coded and placed in a central toxicity file.

7. References, which are numbered and listed consecutively in a bibliography of tabulated data.

8. Evaluation of the reference as to whether it is a review article or a report of original investigations, and how much of a bibliography is cited.

The material selected for tabulation includes both clinical and experimental studies (acute and chronic) on all living organisms with the exception of microorganisms. In general, the effects of submersion, oral ingestion, and absorption through the skin are considered the most important aspects from the viewpoint of water toxicity. However, parenteral injection (in a manner other than through the digestive tract) results are included in the studies tabulated because of their possible value in determining the intermediate metabolic fate of the substances in the test organism.

It is not until tabulation sheets are compiled that the Kettering staff begins the task of making a critical evaluation of information at hand. The first step involves a detailed review of the articles tabulated. This serves as an editorial and factual check on the work of the abstracter. Then a summary is made of information on each substance. With this summary there is included an interpretation of the physiological, pharmacological, and toxicological significance of the substance as revealed by the references at hand.

Obviously, such an interpretation must be viewed as interim in nature until a substantial number of references have been screened and tabulated and certain conclusions are proven beyond question. In this connection it might be noted than on substances being investigated with the aid of the National Cash Register Company eight interim evaluations have already been completed.

During the course of these evaluations, it is found necessary on occasion to discount the conclusions arrived at by several investigators because of new facts uncovered by others. For example, it might be learned that chemical analytical methods were incorrect or too insensitive; or the plan of the investigation was faulty; or the data were too scanty to warrant the conclusions. It is standard practice, therefore, to study the original writings of the investigator, because reviews or abstracts sometimes are found to be inaccurate.

Periodically, a summary statement is prepared by the Kettering staff in which all available data are assembled relating to toxicity as it affects man, domestic animals, aquatic life, and laboratory animals. In each of these classifications the references are noted that state:

1. For short exposure (single dose or repeated doses in one or a few days):

   (a) The highest dose reported as not effective (non-effective level).
   (b) The lowest dose reported to be questionably effective (questionably effective level).
   (c) The lowest dose reported to be effective (effective level).

2. For long exposure (repeated doses over weeks, months, or years):

   (a) The highest dose reported as not effective.
   (b) The lowest dose reported to be questionably effective.
   (c) The lowest dose reported to be effective (effective level).

3. Minimal single dose reported as having caused death.

These levels are listed only when there are what appears to be valid data given in the abstracts. The concentration or dosage levels are subject to change in subsequent reports as additional data become available.

Data on toxic effects of chemical pollutants in the solid diet, in inhaled air, and in injection studies are included where they provide a guide to, and until such time as there is found, information on the effects of these contaminants in drinking water. The summary also indicates the areas in

which little or no information is available on the toxicity of pollutants to man or animals.

The literature abstracts pertaining to the toxicity of aquatic life are referred to the Commission's Aquatic Life Advisory Committee for review and evaluation. This committee is composed of eight of the country's leading aquatic biologists whose role is to define the quality of water suitable for the maintenance of fish life and to determine the procedures by which that suitability is to be measured. The activities of what the Commission considers to be one of its most important committees are, however, beyond the scope of this paper, although it is deemed necessary to point out that in this comprehensive program of toxicity evaluation there is a plan wherein aquatic life considerations are amply recognized.

What Has Been Accomplished

It will be noted from the procedure outlined that the ORSANCO-Kettering project seeks to serve both immediate needs and long-term objectives. The immediate need is to assemble and evaluate as quickly as possible information on toxicity potentials for the Commission, its signatory states, and its industries. The long-term objective is to establish a center for the accumulation of new knowledge on toxicity and provide a clearinghouse from which existing information can be quickly extracted.

How these objectives are being met is evidenced in terms of accomplishments to date.

As a center for toxicologic information on substances in water, The Kettering Laboratory already enjoys a unique position. More than 5,000 reference cards are in its files, and additions are being made at the rate of 300 per month. Of the published material referenced in the card file, more than 525 articles have been abstracted and tabulated. A substantial number of these are from foreign sources, many of which are translated and are not generally available in this country.

With regard to recommendations on the maximum allowable concentrations of substances in water—the consideration of primary concern to the Ohio River Commission and its signatory states—two final reports have been prepared. One of these relates to lead, the other to fluorides. Since these limits are currently under consideration by the Commission and its industry committees, it is not appropriate to discuss the findings at this time. But it should be pointed out that the lead recommendation is based on a background of more than 25 years of investigations conducted by Kettering for other sponsors; and the fluoride recommendation is largely based on work previously undertaken for another group of sponsors. These facts are cited to indicate how the ORSANCO project is benefiting from the great fund of industrial toxicology information already available at Kettering.

Meantime, interim recommendations have been made on concentrations of copper, as well as the chloride and sulfate compounds of sodium, potassium, calcium, and magnesium that affect man and animals. These findings, as well as preliminary data on phenol concentrations, would seem to indicate that the toxic significance is well beyond the ranges in which these substances might be encountered in Ohio River Valley streams. Partly complete are recommendations on maximum allowable concentrations of chromium and cyano-compounds (cyanides, cyanates, thiocyanates, etc.).

One of the more dramatic incidents illustrating the value of the Kettering project occurred more than two years ago. The question was raised whether trace amounts of cyanide in streams might possibly cause poisoning of humans, the signs and symptoms of which were being diagnosed as poliomyelitis. The Kettering investigators subsequently made a special report to the

Commission (see excerpts in *Eng. News-Record*, **148**, 14, 76; Apr. 13, 1952), pointing out that chronic cyanide poisoning does not present a problem of differential diagnosis with polio. The report listed twelve symptoms of poliomyelitis and showed their complete contrast with symptoms associated with cyanide poisoning. Here was an example where a prompt and competent array of facts was marshalled to forestall what could have become a most unfortunate matter of public concern.

Another aspect of accomplishment has been the preliminary classification of chemical pollutants of surface and ground waters as to their toxicity. In this report some 180 chemicals used in industrial processes, in water and waste treatment, and in agricultural practices, are tentatively classified in the following four categories:

1. Pollutants known to be toxic at low levels of concentration.
2. Pollutants considered of lesser toxic importance at low levels of concentration.
3. Pollutants insufficiently studied.
4. Pollutants considered non-toxic in concentrations of less than 1,000 p.p.m.

It should be understood that the sole basis for this classification is the presently available information concerning the toxicity of the substances. Because there are big gaps in such knowledge, the classification is subject to revisions. It does, however, provide a base-line from which future studies can be projected, as well as a basis for assigning priority of attention for closing the gaps.

What Lies Ahead

In this account an attempt has been made to summarize the background and purposes of the ORSANCO-Kettering toxicity project, to outline how the operation is being conducted, and to denote some of the accomplishments.

A fitting conclusion is a word on what lies ahead. When the Ohio River Commission authorized the inauguration of this project it was under no delusions concerning the magnitude of the task to which it addressed itself. The Commission recognized a deficiency in knowledge for proper regulation of stream pollution. From a financial standpoint, however, the Commission also recognized that although it could initiate the development of a project it would also need to inspire collaboration from the many groups and industries having a stake in the application of toxicity determinations.

Substantial support to the project is being provided from two of the industry committees that have been working so effectively with the Commission. Additional support for individual projects and the further development of the central toxicity information file is developing. In this connection, it might be pointed out that The Kettering Laboratory in its performance of research for other sponsors secures data that can be made available for the interpretation of water toxicity potentials. This was so in the case of lead and fluorides. Currently under way at the laboratory is a study of beryllium for the Atomic Energy Commission. Also being investigated are some of the newer chlorinated hydrocarbon insecticides, as well as several organic compounds used in industrial processes and products.

It is believed that the ORSANCO-Kettering project offers rich promise for the years ahead in a better understanding of water quality and toxicity. There are, however, so many aspects to questions on toxicity—and there are such huge gaps in knowledge—that the Commission and The Kettering Laboratory would welcome the interest and collaboration of any who may share an interest in getting answers.

Acknowledgments

Among those most intimately associated with the project acknowledgment is made of the efforts of J. S. Cass, principal investigator, Miss E. Green-

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John E. Kinney, staff sanitary engineer, and the author represent the Ohio River Valley Water Sanitation Commission, the chairman of which is H. E. Moses, director of sanitary engineering, Pennsylvania State Department of Health.

DISCUSSION

By George E. Burdick, Sr.

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Failure of pollution agencies to evaluate all the potential hazards involved in the disposal of industrial wastes to surface waters has been pointed out by Mr. Cleary. Information on the effect of certain chemicals on man is recognized to be extremely sketchy and obtainable mainly from studies of occupational hazards and industrial health and epidemiological studies in certain areas. The project initiated by ORSANCO to accumulate all such references into a common file and have a critical analysis made by those most familiar with the field, is one that can be expected to be very valuable in the final assay of the information on the subject. Inclusion of lower animals and aquatic life in the study, although increasing the time and effort needed for the project, should lead to comprehensive results. Information on the effects of toxic compounds on other warm-blooded animals appears even more scanty than for man. It is certain that a project of this nature could not be attempted by the individual; an integrated cooperative approach is necessary. The cooperation of the industrial committees and their important contributions to the program is encouraging and may establish a pattern for future attacks on water pollution problems.

It is to be hoped that the attempt to develop critical standards for toxicity to man does not presage, or open the way to concerted efforts to require pollution enforcement to be based only upon standards applicable to the requirements of man. If this were to occur, it would constitute a definite backward step in the control of pollution in this country and would open the way to increased pollution, with an accompanying loss in property values and recreational facilities in almost all states which have laws controlling pollution. It seems obvious that the well-rounded pollution control program requires that the critical standards be established on the basis of the least tolerant of the forms on which it has an impact, whether that be man, lower animals, or fish. Furthermore, certain substances that may affect the uses or enjoyment of the water, or act in decreasing property values, also must be controlled even though they may have no toxicological significance.

It has been stated that the toxicity of chemical compounds to fish has received more attention than the toxicity to man. It would be unwise to assume that every foreseeable chemical discharge would be more toxic to fish than to man. However, if the sensitivity of fish to many known toxic chemical wastes was not higher, there would probably be no lack of information on the toxicity of these waterborne chemicals to man. In this re-

spect it should be mentioned that the U. S. Drinking Water Standards must be revised downward if they are also to permit the existence of fish life. Although fish may often serve as a sensitive indicator organism the literature is such a mass of conflicting statements that critical analysis is needed before the data can be applied. Failure to present the complete analysis of the water used often prevents such evaluation and leaves the investigator no choice but to repeat the experimental work using the water to which the discharge is to be made. This type of study is fairly easy with fish, becomes expensive with the lower animals, and seems impossible with man.

Some time ago the State of New York was faced with the responsibility of attempting to set standards to apply to various uses of water. It was considered possible to formulate a guide for certain substances affecting fish life for the average water in the state, but it was also recognized that such levels, if set, would be too high for some waters, whereas others with a different chemical composition might safely carry a higher level. To cover such a situation, use was made of the terminology objected to by Mr. Cleary, which prohibits the discharge of substances which will be toxic after stream dilution. This usage does not imply special knowledge on the part of the administrator, but permits coverage under the law when toxicity can be demonstrated. It is an admission of inadequate knowledge, rather than a claim to specialized knowledge, and an attempt to establish a concept in the law which can grow with increasing information.

It is a difficult thing to set an arbitrary standard for waterborne toxicity to man and involves a responsibility on the part of the administrator which can be extremely dangerous. It probably should not be attempted unless all phases of possible reaction and counteraction have been thoroughly explored. Whether or not the setting of such standards will be possible or even desirable as a result of the ORSANCO program remains to be seen, but aside from such possibility the program appears to fill a definite need. The Ohio River Valley Water Sanitation Commission is to be congratulated on its approach to the problem. The Commission is fortunate in being able to draw on the facilities of The Kettering Laboratory, with its well-trained staff and long experience in the studies of occupational hazards and industrial health. Much of this previously acquired knowledge is capable of nearly direct transference to the field in which the Commission is interested and this is already paying dividends. The problem is not an easy one and the answers are not easily obtainable, but it should lead to marked improvement of knowledge in this field where far too little is known.

One phase of the Kettering program which seems of major importance has been mentioned, but not stressed, in the presentation. This is the plan for working out, or suggesting new or improved analytical methods for use on effluents, stream quality determinations, or biological investigations. It would be useless to set any standards for stream quality unless sufficiently exact and accurate methods are available to determine when these standards are violated or are in danger of being violated. One of the major handicaps in stream pollution control today is the fact that far too many substances, many of them of known toxicity to aquatic life, have not yet had simple, exact analytical methods developed for their determination at and around their toxic level. This part of the program should interest and be of value to nearly every agency concerned in the alleviation of stream pollution, as well as to every industry interested in reducing and controlling the effect of industrial discharges on the receiving waters.

HIGH-RATE ACTIVATED SLUDGE TREATMENT AND ITS RELATION TO STREAM SANITATION

II. Biological River Tests of Plant Effluents *

By K. Wuhrmann

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A previous paper (3) described experiments on sewage treatment at much higher rates than usual and stated that the results achieved would satisfy rather high requirements of river pollution control. Of course it could not be overlooked that plant effluents with B.O.D.'s as high as 20 to 25 p.p.m. are to be expected, even with relatively diluted sewage (140 p.p.m. B.O.D. in the raw sewage after plain sedimentation). In addition, these effluents are practically oxygen-free.

The great majority of the rivers to which Swiss communities discharge their sewage are of the shallow turbulent type, mean water depth often less than 1 ft. and rarely exceeding 6 to 8 ft. (mostly in dammed rivers). In general, flow is more than 1 ft. per second, with most flows between 3 and 6 ft. per second, or more. River beds are usually very rough (gravel and rocks). It is obvious that, due to these flow conditions, high oxygenation coefficients are observed, and, moreover, self-purification is predominantly accomplished by the flora and fauna of the river beds.

It was concluded, therefore, that quality requirements of plant effluents based on the oxygen balance of the receiving river might not be an adequate method for determining the dimensions of purification plants. This method should be replaced by a continuous relation describing the character of the river biocoenosis and the chemical properties of river water after introduction of plant effluents. It is evident that the rather incomplete knowledge of the specific ecological requirements of the organisms involved limited this far-reaching program. It was decided first of all to describe river biocoenosis in terms of the relative abundance of heterotrophic and autotrophic microphytes (roughly speaking). Thus, plant effluents when introduced to a river must only induce a biocoenosis of autotrophic organisms; no heterotrophic growth should be visible to the naked eye. It was assumed that the prime nuisances of sewage influents, insofar as esthetic considerations, fisheries, etc., were concerned, might thus be eliminated.

Systematic investigation of the relation between water composition and biocoenosis on an experimental basis is only possible in artificial rivers. In these rivers the required conditions can be rigorously maintained for indefinite periods. Channel tests for river sanitation studies were first made by Streeter (4)(5)(6). Later, Mahr (7) also published a paper on model tests, including certain biological considerations. Both authors had channels of small cross-section at their disposal; thus, biological investigations could not be accomplished on a "natural" basis.

From the experience gained earlier by Blöchlinger and Husmann (8) and Thomas (9), a system of five parallel, concrete channels with a length of

* Abstracted from two papers by the author (1)(2) published in German.

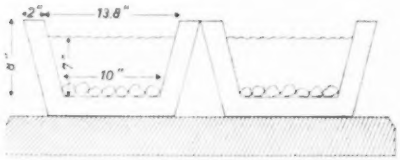

FIGURE 1.—Cross-section through experimental stream channels.

about 400 ft. each was added to the pilot plant, as previously described (3). Further constructional details are indicated in Figure 1. The channel slope was 0.15 per cent. With a fill of one layer of 1.5-in. gravel, a water depth of about 6.5 to 7.5 in. was maintained at a feed of 1.75 gal. per second. Figure 2 is a photograph of the channel system.

Experimental Methods

As previously mentioned, the aim of the experiments was (a) to test the quality of the effluents from the pilot plant biologically and to estimate the proportion of dilution necessary to avoid any nuisance in a river, and (b) to establish a continuous relation between the chemical composition of river water and the kind of biocoenosis induced in the river.

As a rule, the plant effluents to be tested and the respective raw sewages were added at constant flow to the channels, fed with clean river water, the total channel flow being always 1.75 gal. per sec. One channel served as a control; that is, it received no pollution at all. By trial and error (with experiments at different dilution factors for each effluent), the minimum dilution was estimated which still assured a tolerable type of organism in the river (apparently free from heterotrophic microphytes).

The duration of an experiment was limited to 4 to 6 weeks, a balanced state of the composition of the river growth being achieved after about 3

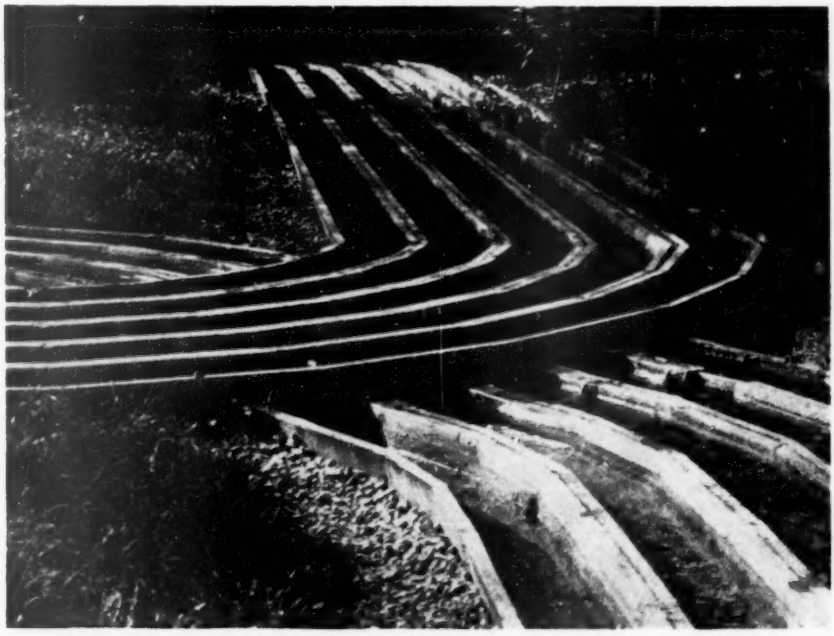

FIGURE 2.—View of experimental channels at the cross-over point (see Figure 2 of Ref. 3).

TABLE I.—Average Composition of Dilution Water for the Channel Tests

Characteristic	Summer	Winter
Oxygen saturation (%)	100	100
B.O.D., 5-day (p.p.m.)	2 to 2.5	2 to 2.5
Oxygen cons., $KMnO_4$ (p.p.m.)	10	10
Total nitrogen (p.p.m.)	0.5	1.4
Organic nitrogen (p.p.m.)	0.3	0.3
Total phosphorus (p.p.m.)	0.07	0.07
Temperature (°C.)	17 to 22	2 to 8

weeks. The later development was merely of a quantitative character. Between each experiment the channels were cleaned mechanically and chlorinated. The dilution water applied was pumped from the Limmat River (effluent from Lake of Zurich), having an average composition as given in Table I.

River-water analyses (24-hr. continuous samples) were made on the same days as plant effluent and raw sewage analyses (see Ref. 3). The composition of the channel water could then be calculated according to the dilution factors. This method was more economical than special channel-water analyses and also more precise. Ten to 20 analyses (24-hr. composite samples) were needed for one experiment, since any given biocoenosis is the effect of the mean composition of the flowing water over a period, which must not be too short. The growth of organisms was followed regularly by microscopic inspection of samples and the macroscopically visible distribution of organisms was carefully noted. Only that part of the organic layer in direct contact with the overflowing water was considered as significant for further evaluation, because organisms lower in sludge deposits are no longer directly related to the composition of the flowing water. Considering the main purpose of the experiments, the final results gave evidence that the macroscopically visible quantity and distribution of heterotrophic and autotrophic organisms in the channels were the most important criteria.

The correlation between the biocoenosis and river-water composition was based, therefore, on the observation classification given in Table II. This scheme describes the channel state in terms of the relative abundance of *Sphaerotilus*, which was the predominant and practically the only heterotrophic organism of significance. At low pollution, abundant growth of ciliates in macroscopic colonies was observed when *Sphaerotilus* could develop no further. Similarly, at very high pollution *Sphaerotilus* decreased or disappeared completely and was gradually replaced by a layer of "sludge" (free and zoogloea-forming bacteria, flagellates, etc.), often covered with *Beggiatoa*.

TABLE II.—Classification Scheme for the Growth in Experimental Channels

Classification	Result of Macroscopic Inspection of the Layers of Organisms in Direct Contact with the Overflowing Water
0	Autotrophic microphytes only. Slow development. Large number of species, but small number of individuals.
3	Autotrophic microphytes dominant, but small colonies of sessile ciliates clearly visible.
5	Autotrophic microphytes dominant, *Sphaerotilus natans* or other heterotrophic filamentous microphytes visible in small colonies; or sessile ciliates in large whitish colonies.
7	Proportion in relative abundance of autotrophic and heterotrophic microphytes around 1:1.
9	Heterotrophic microphytes dominant, autotrophs still persisting in clearly visible groups.
11	Heterotrophic microphytes only, forming mass developments (mostly *Sphaerotilus*). Formation of thick anaerobic sludge layers below surface growth.
13	Heterotrophic microphytes only. Anaerobic associations even in surface layer of growth. Sulfur bacteria frequent.

The autotrophic component of the biocoenosis in the channels was treated in this evaluation as an entity. Of course it would be highly desirable to replace this simple qualification scheme by one based on many more individual organisms whose physiological and ecological properties are well defined. Unfortunately, so far there is no basis for a sound sociological differentiation of groups of organisms, quantitatively related to the composition of the water. The well-known scheme of Kolkwitz and Marsson (10) is neither based on sound sociological principles nor has it been established in a quantitative relation to the degree of water pollution. A tentative approach to a sociology of river organisms has been made by Margaleff (11) Simoyen (12) and others, but these investigations only cover autotrophic associations.

Results

Correlation of River Water Quality and Growth Classification

In the course of the different experimental series with the activated sludge pilot plant, 25 channel experiments with purified or raw sewage were carried out under sufficient analytical and biological control to justify detailed evaluation.

It is a reasonable procedure to correlate individual components of the chemical composition of the channel water and the results of the biological observations (when growth development is in equilibrium with water composition). This has been done for B.O.D., organic nitrogen, and oxygen consumed from potassium permanganate (this latter parameter has only been measured in a small number of experiments). The results are graphically represented in Figures 3, 4, and 5. Each point represents one channel test. The following conclusions have been drawn from the graphs:

1. The results of the individual tests; that is, the character of biocoenosis correlated with the chemical components of the water in the respective run, form curves depending on the kind of polluting water used for the channels. Points resulting from dilution of raw sewage or from dilution of low- or high-rate activated sludge plant effluents may be connected by continuous curves. This is remarkable in that the different runs, represented by the points of the regression lines, have been obtained at quite different times

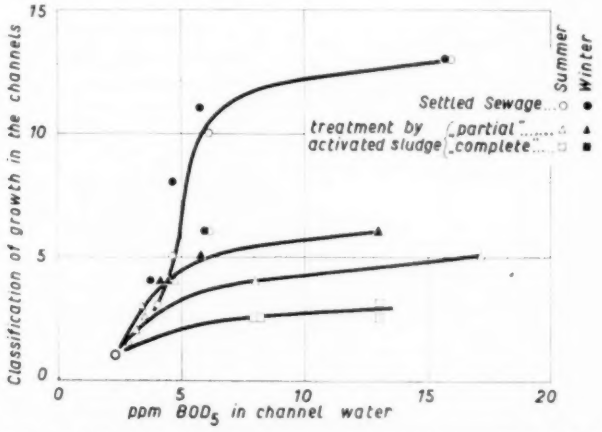

FIGURE 3.—Relation between character of channel biocoenosis and B.O.D. of channel water.

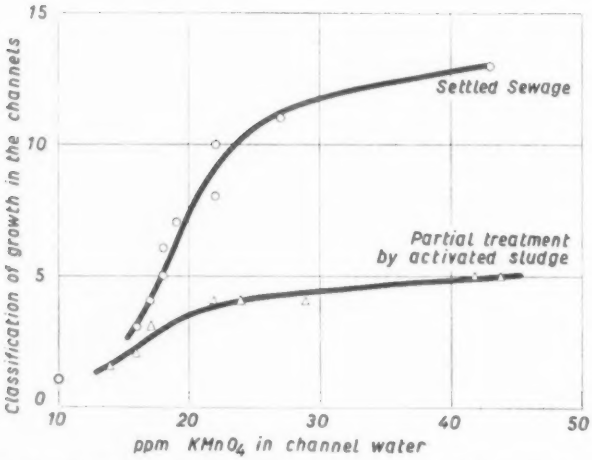

FIGURE 4.—Relation between character of biocoenosis and oxygen consumed (from $KMnO_4$) of channel water.

(within a period of four years). It is unlikely, therefore, that the regressions are a mere matter of chance.

2. Similar values of B.O.D., oxygen consumed, or organic nitrogen in the channel water produce very different associations of organisms. The biocoenosis in the different runs depends on the nature of the polluting water chosen. For instance, when raw sewage is diluted to a B.O.D. of 10 p.p.m. in the channels, a completely heterotrophic flora results. On the other hand, when the same is done to a treated effluent (with a lesser degree of dilution, of course) an association is produced in which there is only slight heterotrophic growth or none at all.

3. There are no differences visible between summer and winter experiments, except for the regression of the B.O.D. values of high-rate activated sludge effluents. No explanation

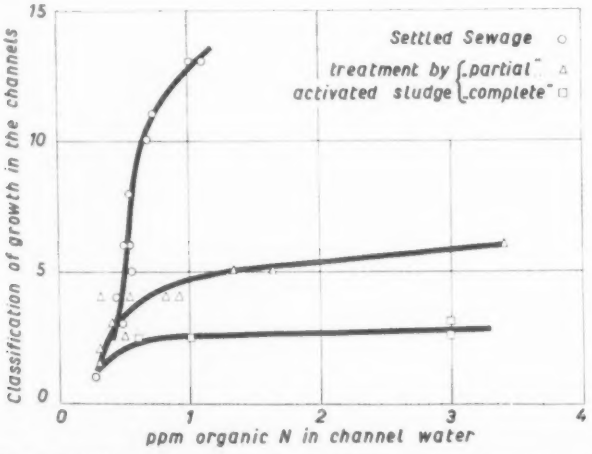

FIGURE 5.—Relation between character of biocoenosis and organic nitrogen in channel water.

is possible for this observation and further investigation is needed for this problem.

4. Low-rate activated sludge effluents promoted no primary growth of heterotrophic organisms in macroscopically detectable colonies, even when applied undiluted. Heavy eutrophication occurred, however, due to the high concentrations of inorganic nutritional ions in the undiluted water. This forced production of autotrophic organisms led invariably to secondary pollution in longer experiments, similar to that observed in natural rivers.

It seems rather difficult to explain satisfactorily the results of this correlation study. It is surprising that the same amounts of B.O.D., organic nitrogen, or oxidizable substances (the same holds true for organic carbon) in water promote rather different associations of microphytes. The "biological activity" of these compounds depends, apparently, on the pretreatment of the polluting water fed to the channels.

As far as B.O.D. is concerned, incomparable B.O.D. estimations (nitrification) in the different channel tests might be suspected as a reason for the discrepancies observed. Careful control has shown, however, that nitrification in B.O.D. tests never occurred to any significant degree. It is thought that the following interpretation of the observations in the channel tests should be considered: B.O.D., organic nitrogen, organic carbon, oxygen consumed, etc., are analytical procedures that lump together large groups of substances, having extremely diversified chemical constitutions. From the biochemical point of view it is, therefore, quite impossible to define with such analytical figures a "milieu" for living organisms. Thus, the relations in Figures 3, 4, and 5 are merely an expression of the fact that various compounds, which add much more to B.O.D., organic nitrogen, etc., in raw sewage than in treated effluents, are of high physiological value to certain heterotrophic organisms. This interpretation leads to further conclusions, namely:

1. High-rate activated sludge treatment of sewage is a fermentation process as well as low-rate treatment, although a somewhat lower elimination of easily fermentable substances occurs.

2. It seems theoretically impossible to achieve the same degree of river pollution control by dilution of effluents from plain sedimentation plants as by dilution of biologically treated sewage, because sedimentation alone does not change the character of a sewage. In practice, however, the concentration of fermentable substances in settled sewage can be diminished to such a degree, by dilution in rapid flowing rivers, that growth of heterotrophic organisms is almost excluded. The necessary dilution factors have been estimated experimentally and are reproduced in Figure 6.

3. The same considerations must be adopted for sewage treatment by plain sedimentation combined with artificial coagulation, unless it can be proved that dissolved fermentable substances

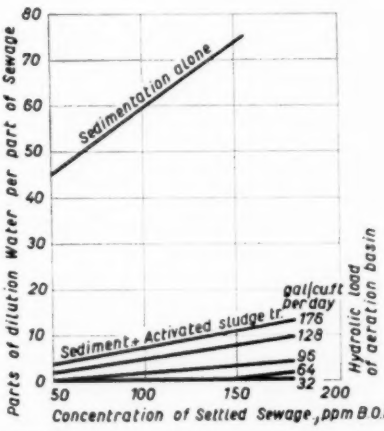

FIGURE 6.—Dilution requirements for sewage after activated sludge treatment at different rates when only autotrophic organisms are permitted in river growth (fauna not considered).

are quantitatively absorbed by the coagulant.

4. River water containing settled raw sewage in such a low concentration that the oxygen balance is no longer affected, may nevertheless be a considerable nuisance in drinking water treatment plants, aquifiers (after infiltration), etc., due to unfermented dissolved organic matter. These substances, which could be easily removed by biological sewage treatment, promote the well-known growth of slimy organisms in conduits, and are the reason for complete oxygen depletion of underground water, followed by dissolution of iron and manganese. Several striking examples of such nuisances are well-known in Switzerland.

Dilution Factors for Activated Sludge Plant Effluents

It was mentioned previously that the channel tests formed an integral part of the experiments on high-rate activated sludge treatment of domestic sewage. It may be of interest to compare the efficiency of the treatment plant with the results of the channel tests in the respective runs. Table III summarizes 15 channel experiments with treated effluents. The tests are listed according to the classification of the river biocoenosis observed. Assuming the biological condition in a river as "tolerable" when no or only very slight growth of heterotrophic organisms is produced, the upper part of Table III contains the favorable experiments. Two channel tests with high-rate treated sewage at low dilution reached the satisfactory limit and one (with no dilution) was unsatisfactory. The table demonstrates that even at high plant loads effluents are produced that need only low dilution factors to avoid detectable growth of undesirable organisms. For effluents from low-rate treatment plants (that is, less than 75 lb. B.O.D. per 1,000 cu. ft. per day), no dilution at all was necessary. This is in agreement with observations on receiving water bodies of many treatment plants in the United States and in England.

TABLE III.—Character of Channel Growth in Equilibrium with Diluted Effluents of the Activated Sludge Pilot Plant

Plant B.O.D. Loading (lb./1,000 cu. ft./day)	Final Effluent B.O.D. (p.p.m.)	Dilution Water-Sewage Ratio	Channel Growth Classification
84	13	19	1 to 2
16	13	0	2 to 3
17	8	0	2 to 3
23	8	0	2 to 3
76	15	14	2
86	13	9	2 to 3
76	15	11	3
106	16	10	3
84	13	5	3 to 5
73	13	4	3 to 5
158	32	4	3 to 5
191	25	9	3 to 5
73	13	2	5
158	32	1	5
73	13	0	5 to 7
Control*	2	—	1 to 2

* Control channel, no pollution.

Assuming an entirely autotrophic flora in rivers as a parameter, and combining the results of the channel tests with activated sludge plant performances according to Figure 9 in Ref. 3, Figure 6 can be traced. This graph contains the dilution factors for effluents of the experimental activated sludge plant operated at different hydraulic loads with settled sewage of various concentrations. The dilution factors for settled raw sewage are indicated for comparison. Once more it is demonstrated that biological treatment of sewage, even at very high rates, is much more effective from the biological point of view than sedimentation alone. Fig. 6 is based on a B.O.D. of 2 p.p.m. in the receiving river and on flow conditions as described in the opening paragraphs of this paper.

Final Remark

One may discuss the significance of the channel tests from the practical point of view. As long as the channels are only used as a large "test tube"—that is, as an additional analytical tool for the estimation of fermentable substances in sewage—no objection can be made. But what about the transfer of the results of channel experiments to natural water bodies?

In nature, the type of associations of microphytes in rivers depends predominantly on the factors of composition of the river water, hydraulic conditions, illumination, and temperature. In artificial channels, only very limited variations of flow and water depth are possible. Velocity of flow, however, influences the type of organism association to a great extent (other variables being equal). The transfer of the results of channel tests to natural watercourses is therefore restricted to rivers with similar flow conditions. Moreover, the relatively slight water depth in the channels greatly favors oxygen uptake and illumination of the bottom flora compared with deep natural rivers. It is impossible, therefore, to use the test channels as models for deep sluggish streams. These limitations do not, however, decrease the value of such channel tests, because the direct biological evidence which can be gained from them is a very valuable supplement to chemical analyses of effluents from pilot plants.

Summary

Taking the relative abundance of heterotrophic and autotrophic microphytes in the bottom flora of model rivers as a measure of the degree of water pollution, the following observations were gained experimentally:

1. There exists a good correlation between the type of river biocoenosis and the concentrations of polluting matter in the water, measured by means of B.O.D., organic nitrogen, organic carbon, or oxygen consumed from potassium permanganate.

2. The regression curves expressing these correlations depend on the source of the polluting matter. Equal "concentrations" of B.O.D., organic nitrogen, etc., achieved in a river by dilution of settled or biologically treated sewage do not produce comparable associations of microphytes. Dilution of settled sewage to such a degree that detrimental effects on the oxygen balance of shallow, turbulent streams are excluded, may still induce quite undesirable growths of heterotrophic microphytes (for instance *Sphaerotilus*).

3. Channel tests proved that sewage treatment by the high-rate activated sludge process is sufficiently effective for river protection in many cases. [Example: a settled domestic sewage with a B.O.D. of 140 p.p.m. needs dilution with at least 75 to 100 parts of clean river water (B.O.D. = 2 p.p.m.) to avoid visible growth of typical "sewage organisms" (*Sphaerotilus*, ciliates in macroscopic colonies, etc.). After high-rate treatment of the same sewage (hydraulic load of 150 g.p.d. per cubic foot, effluent B.O.D. of 22 p.p.m.) a dilution with 10 parts of river water is sufficient to avoid any nuisance by undesirable organisms.]

4. The channel experiments gave evidence that biological treatment of domestic sewage produces quantitative as well as qualitative alterations of sewage compounds, which cannot be detected by the usual comprehensive criterions such as B.O.D., organic nitrogen, organic carbon, etc.

References

1. Wuhrmann, K., "Über die biologische Prüfung von Abwasserreinigungsanlagen." *Ges. Ing.*, **72**, 253 (1951).

2. Wuhrmann, K., "Erfolgreicher Gewässerschutz." *Strasse u. Verkehr*, **5**, 120 (1951).

3. Wuhrmann, K., "High-Rate Activated Sludge Treatment and Its Relation to Stream Sanitation. I. Pilot-Plant Studies." THIS JOURNAL, **26**, 1, 1 (Jan., 1954).

4. Streeter, H. W., "Comparative Rates of Stream Purification under Natural and Controlled Conditions." *Eng. Chem.*, **22**, 1343 (1930).

5. Streeter, H. W., "Measures of Natural Oxidation in Polluted Streams. I. The Oxygen Demand Factor." *Sewage Works Jour.*, **7**, 2, 251 (Mar., 1935).

6. Streeter, H. W., "Measures of Natural Oxidation in Polluted Streams. II. The Reaeration Factor and Oxygen Balance." *Sewage Works Jour.*, **7**, 3, 534 (May, 1935).

7. Mahr, G., "Versuche zur Selbstreinigung von Gewässern." *Jahrb. v. Wasser*, **11**, 198 (1936).

8. Blöchlinger, G., and Husmann, W., "Beitrag zur Kenntnis der Wachstumsbedingungen von Abwasserpilzen in fliessenden Gewässern." *Z. Hydrol.*, **8**, 55 (1939).

9. Thomas, E. A., "Versuche über die Selbstreinigung fliessenden Wassers." *Mitteil. Lebensmitteluntersg. und Hyg.*, **35**, 199 (1944).

10. Kolkwitz, R., "Ökologie der Saprobien." *Schriftenr. Ver. Wasser-, Boden- und Lufthyg.*, No. 4 (1950).

11. Margaleff, R., "Las Asociaciones de Algas en las Aguas dulces de pequeño Volumen del Noreste España." Vegetatio, Acta Geobotanica, **1**, 258 (1948).

12. Simoyen, J. J., "Esquisse d'un système des associations algales d'eau douce." *Proc. Int. Assn. Theor. Appl. Limnology*, **11**, 395 (1951).

REPORT ON SEWAGE SERVICE CHARGES

In a recent report entitled "Sewage Service Charges in Cities Over 5,000 Population," a special committee of the American Public Works Association gives the results of a study of sewer provisions in 581 U. S. cities in that population grouping. According to the 35-page report, more than $8,000,000 is collected annually from sewage service charges in these cities. Also, sewage service revenues range from about 5 per cent to as high as 50 per cent of the property tax yield in cities of that size where property taxes brought in less than $24 a year per capita.

Charges for residential sewage service stay about the same in cities of the same population group, regardless of whether the city is surburban, a central metropolitan area, or an independent city, and regardless of the city's manufacturing importance.

The report points out that demands for municipal services have heightened with the growth and shift of population to urban areas and with social and technological progress. Sewage disposal is one of the services citizens have come to expect from their local governments, says the report, adding that governments in turn have needed extra funds to meet the new costs. Sewage service charges have been the answer in many cases.

Of 233 municipalities responding, 15 cities of more than 100,000 population reported an average per capita revenue of $2.57 from an average monthly charge of $0.57 for residential service, based on a monthly use of 5,000 gal. of water. For cities under 100,000, the average per capita revenue was $3.20, the average monthly charge being reported as $0.82.

Billing and collecting practices also were surveyed in more than 150 cities. About 31 per cent require deposits varying from $2 to $50, the most common being $5. In 53 per cent the tenant gets the bill; 27 per cent reported that the owner is billed. Of the remaining 20 per cent, some bill whoever applies for the service and others follow the owner's wishes in the matter. Some tenant bills are transferable to the owner's responsibility so that overdue bills can be transferred to the tax rolls. Quarterly billing is most common in the midwest, monthly billing in the southwest, and annual billing in the east. Commercial properties and large users are likely to be billed more often than residents. The smaller bills do not justify the expense involved in computing the charges and preparing and mailing the bills at too frequent intervals. On the other hand, it is often considered easier to pay bills if they are not too large, justifying more frequent billing of accounts involving higher charges.

The report, designated as Special Report No. 18, is available at $2.00 per copy from the American Public Works Association, 1313 East 60th St., Chicago 37, Ill.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

GADGETS—A NEW OPERATION EFFICIENCY INDEX?

Of the many phases of sewage treatment plant operation there probably is no single phase which stands out with more clarity as a credit to the operator than the gadgets that have been devised to assist in plant operation. This is true because, on the whole, such gadgets are usually the result of the ingenuity of the plant operator alone. There have been few sewage treatment plants constructed which have operated in every detail exactly as planned on the blue prints. Equipment which may have operated in one plant without difficulty may need specific attention elsewhere.

It would be difficult to find a sewage treatment plant operating without the aid of tools and refinements conceived and constructed by the plant operator. Indeed, a plant whose personnel has not contributed a number of homemade expedients to ease its operational duties and safety hazards might well be found to have a staff that lacks the enthusiasm so necessary to alert and proper operation. To be considered also is the caliber of the operation staff assigned to a plant. An improperly staffed plant, or, for that matter, an improperly budgeted plant, will seldom be able to compete with a plant operating with a full complement of adequately trained men sincerely interested in top performance.

Regarding the subject of plant inventions, it cannot be too strongly stressed that at no time should safety be sacrificed in order to bring forth a gadget merely for the purpose of displaying ingenuity. No thinking operator would attempt to construct a homemade gas-fed chlorinator to do the job when such excellent equipment is commercially available.

Another precaution should be mentioned. Although the manufacturers of sewage treatment plant equipment are generally highly cooperative and attentive to the operator's needs and suggestions, certain respect must be shown their rights, legally and otherwise. Patented devices are protected by law.

As pointed out elsewhere in THIS CORNER, the literature contains many references to gadgets, both large and small. No operator, therefore, should ever hide behind the wall of ignorance or inertia, as the basis for improvements to his plant, even if only of minor nature, has already been provided him. All that is necessary is for him to read, then think about what he has read in terms of his own plant operation, and then go on from there.

Various organizations have sponsored gadget contests for operators. In checking through the literature and noting the winners in such contests there stands out a clear and distinct fact: the plants which had the better operating records were also the ones contributing the largest number of useful gadgets for their fellow plant operators. Is it possible that gadgeting constitutes another index for good plant operation?

GEORGE T. LOHMEYER,
Guest Editorialist

SEWER MAINTENANCE PRACTICE IN LOS ANGELES *

By W. A. Schneider

Director, Bureau of Sanitation, Department of Public Works, City of Los Angeles, Calif.

The Sewer Maintenance Division, one of four divisions of the Bureau of Sanitation within the Department of Public Works, is responsible for the maintenance, operation, and repair of all public sanitary sewers, storm drains, open channels, and appurtenant structures and plants, excepting sewage treatment plants, in the City of Los Angeles. Since Los Angeles City is an incorporated municipality of more than 2,000,000 residents living within an area of 454 sq. mi., the collection systems involved are quite extensive.

There are therein 3,789 mi. of sanitary sewers. This is exclusive of house connection sewers, which under Los Angeles City municipal policy are maintained by the property owners and not by the city. Under relatively recent bond issues totaling $31,000,000 for the construction of trunk, interceptor, and relief sewers, an expansion is under way which will permit the construction and connection of many more miles of new local sewers in major portions of the outlying presently unsewered areas of the city now served by approximately 126,000 cesspools and septic tanks.

The separate storm drain system consists of 779 mi. of storm drains served by more than 30,500 catch basins. This system also is undergoing material expansion because of serious regional flooding in certain portions of the city during the winter rainy seasons of 1951–2 and 1952–3.

Division Organization

To meet these conditions it has been deemed necessary to organize the Sewer Maintenance Division in a manner best suited to perform its diversified work in the most efficient and flexible way. To accomplish this the Division is divided into an administrative section and four operating sections, the duties of which are as follows:

1. The Administrative Section provides the supervision, coordination, and direction for the operating sections; prepares technical and administrative reports, correspondence, annual reports, and annual budget requests; and maintains cost, personnel, and work reports.

2. The Pipeline Maintenance Section is responsible for the inspection, cleaning, repair, and maintenance of all city sewers, storm drains, culverts, and catch basins. These operations are conducted from five district yards, as follows:

(a) North District Yard, serving an area of approximately 75 sq. mi. with an estimated population of 629,000.

(b) South District Yard, serving an area of approximately 61 sq. mi. with an estimated population of 751,000.

(c) West District Yard, serving an area of approximately 85 sq. mi. with an estimated population of 249,000.

(d) Valley District Yard, serving an area of approximately 212 sq. mi. with an estimated population of 350,000.

(e) Harbor District Yard, serving an area of approximately 24 sq. mi. with an estimated population of 91,000.

With the extension of sewers into the more remote formerly unsewered areas, plans are being made for the acquisition and development of two additional yard sites in order to serve the extended sewered areas promptly and without excessive travel time.

* Presented at 26th Annual Meeting, Federation of Sewage and Industrial Wastes, Assns.; Miami, Fla.; Oct. 13–16, 1953.

3. The Channel Maintenance Section is responsible for the cleaning and maintaining of 301 mi. of open channels in the city. This includes the removal of weeds and brush, the construction of fences to protect abutting property, and the removal of accumulated silt and debris deposited in the channels by storm waters.

4. The Operation and Repair Section is responsible for the operation of all sewage and storm-water pumping plants, the sewer ventilating plants, and the mechanical and electrical maintenance of all plants and equipment of the Division, as well as the maintenance of the electrical installations of the Refuse Collection and Incineration Divisions of the Bureau. The testing of the thousands of manholes on the sewer and storm drain systems in the city for possible explosive gas conditions, an activity previously discussed (1), is also a duty of this Section.

5. The Industrial Waste Control Section is responsible for maintaining adequate regulation of industrial wastes into sewers, storm drains, open channels, and rivers to protect the city's interests in the receiving, transporting, and treatment of such wastes. The rapid industrial growth of the city during the past 1943–53 decade has greatly increased the need for controlling the discharge of industrial wastes into the city systems. Further emphasis was placed on this activity by the adoption of the State Water Pollution Control Act in 1949. The Section issues permits for the discharge of this type of waste into the sewers, storm drains, or channels, and requires, where necessary, clarification or pretreatment by the permittee, to condition the wastes prior to their discharge into the city systems.

Use of Employee Skills

The foregoing organization provides a flexible working organization, having regularly assigned specialized groups delegated to the various sections in proportion to the respective regular work loads. Temporary abnormal work loads brought about by storms affecting certain districts of the city more than others, by sewer failures, or by the more extensive repair jobs, are promptly met by the temporary assignment of crews from the less affected districts to those most affected during the emergency.

It has been a set policy to provide in-service training and to encourage employees to broaden their respective skills so that flexibility of individual as well as unit assignments can be effectively used during emergencies, and to provide the individual employee with an opportunity to improve his skills for advancement within the Division. This policy has provided dividends through a high level of employee morale and an improved field of candidates for promotion within the Division.

Emphasis on Preventive Maintenance

Great emphasis is placed on preventive maintenance and the correction of potential sources of failure or trouble before trouble occurs. This has resulted in an exceptionally clear operating experience both in the pipelines and channels and in the 32 pumping plants and 4 sewer ventilating plants. All of the 27 sewage pumping plants and five storm-water pumping plants are automatic in operation and, with the exception of one large sewage pumping plant where an operator is on duty 24 hr. per day, require only daily inspection for correct operation and maintenance. The pumping plant operators under this program are each responsible for 5 to 9 plants; the program appears sound, as only a minimum of mechanical or electrical equipment failures have been encountered. The large majority of the pumping plants are equipped with floatless, electric, liquid level controls (using electrodes of the Division's own design and manufac-

ture) for the pump motor controls, and the low maintenance demands of these units have contributed to the success of the program.

Odor Problems

One of the most critical problems, particularly from a public relations viewpoint, is the effective control of sewage odors along the routes of the outfall sewers (the longest is 55 mi. long). The upper part of this outfall sewer, serving the San Fernando Valley, ranges in size up to about a 5-ft. elliptical conduit, which roughly parallels the Los Angeles River and is carried across the river at several points by means of inverted siphons.

With the tremendous growth in population and development of the city area this outfall sewer now passes through many densely built-up residential districts and emissions of odorous sewer atmosphere brought about in the normal "breathing" of the sewer in certain areas of high odor concentration are a cause of immediate local complaints. This is particularly true at the upper ends of the siphons which, of course, obstruct the normal flow of air above the sewage, resulting in a build-up of air pressure within the sewer upstream from the siphon, with consequent release of sewer atmosphere to the surrounding area. In order to localize the problem, one permanent and some temporary ventilation stations (Figures 1 and 2) have been constructed to withdraw the odorous air from the sewer immediately above the siphons and in each case discharge it at a nearby location, relatively isolated where possible. Although the discharge is made from vertical stacks at relatively high velocity and considerable atmospheric dilution is obtained after discharge, some complaints of objectionable odors continued to be received from residents nearest the ventilating stations. Hence an endeavor was made to find some means of counteracting the odors. Several methods were experimentally tested, including scrubbing, activated carbon, masking, dilution, oxidation, and combinations of these, without satisfactory results.

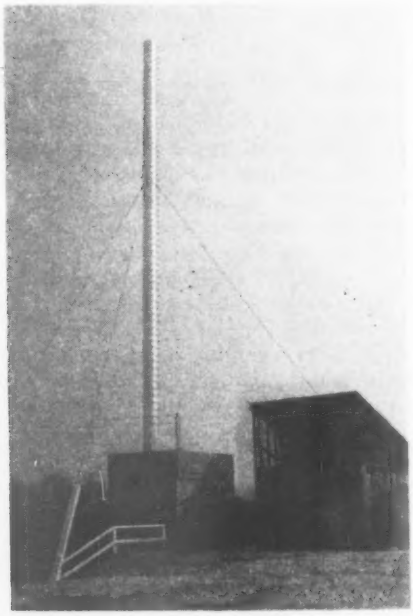

FIGURE 1.—Sewer ventilating station providing 3,290 c.f.m. air movement at 2-in. water static pressure. Temporary sloped roof building adjoining was used for experimental thermal oxidation and other deodorizing tests.

Inasmuch as conditions undoubtedly will change markedly upon completion of a relief sewer system now under design, some temporary measures for odor control have been adopted and used, particularly during the warm season when the odor problem is aggravated. Experimental use of a proprietary odor counteractant product was undertaken, both with and without the addition of an alkaline solution, by aspiration into the ventilation station exhaust duct in one instance and into the sewer itself in another. Lime water was used as the supplemental additive for a time; although it was effective it caused clogging. Sodium carbonate solution is now used as the

FIGURE 2.—Partial interior view of ventilating station shown in Figure 1.

additive. Although this method has not been 100 per cent effective, there has been a reduction in the number of complaints received when application has been continuous. Search is still being made for a more effective and economical solution to this vexing problem.

Explosive Gas Survey

Shortly after a serious gas explosion in 1936 the Sewer Maintenance Division established a regular Explosive Gas Survey service for the purpose of determining the presence of explosive gas within the sewer and storm drain systems, thereby permitting preventive steps to be taken before such gases accumulate in explosive concentrations or before ignition takes place. To this task is assigned one truck of the route van type, with a crew of two men. The special truck and equipment developed for this specialized work has been described elsewhere (1). Field tests are made by simply driving the truck, which is painted a bright orange-yellow with black striping to provide high visibility for traffic safety purposes, along the street adjacent to the manholes to be tested, inserting the small-diameter tip of the prod into the pickhole of each manhole cover about 2 or 3 in., then depressing the electrical push-button on the handle, and observing the indicator readings. This is a relatively fast operation, performed completely from within the truck cab. Because each manhole is tested without stopping the truck, 300 to 500 manholes are tested daily, dependent upon traffic conditions encountered and the average distance between manholes. Immediately the indicator registers a dangerous or potentially dangerous condition, the crew again tests the suspected manhole and confirms or disproves the original readings. Experience has indicated that the large majority of explosive conditions are created by seepage from gas company mains through the soil into the sewer or storm drains, through joints or cracks, where it gradually builds up to dangerous concentrations awaiting ignition. Infrequently the presence of gasoline vapor is found, generally from leakage of nearby underground gasoline storage tanks.

Upon observing and confirming a dangerous condition of gas accumulation the gas company is immediately notified by telephone, with written confirmation given later. The gas company inspects, tests, makes necessary repairs, and advises the Division of its findings and action. Dangerous conditions due to gasoline leakage are immediately reported to the Fire Department, which promptly takes steps toward correction

of the cause. Streets are barricaded and temporarily withdrawn from public use where the conditions are deemed to warrant such action. Splendid cooperation has been given by all utility companies, and others, involved in these problems. The program has been so eminently successful that local utility companies having underground systems now carry on their own explosive survey of their facilities and have as a preventive measure provided special venting for some of their underground vaults and conduits.

Pipeline Maintenance

The Pipeline Maintenance Section, consisting of 42 field crews, as previously stated is responsible for the inspection, cleaning, repairing, and maintaining of all city sewers, storm drains, culverts, and catch basins. Cleaning and inspection crews in general consist of three to four men, including a Working Foreman. Pick-up crews, which collect and dispose of catch basin and other cleanings removed by cleaning and inspection crews, are two-man crews. On repair jobs regular crews may be reinforced by temporarily assigning additional members from other crews where the size or nature of the job indicates such action to be desirable.

Increased reliance is being placed on the use of sewer balls and sewer cones where normal cleaning of sand, silt, or debris is required from sewers 24 in. or less in diameter. These types of tools, winch controlled, have been found to do an excellent job of cleaning where heavy grease or roots are not encountered. Frequently, 5,000 to 6,000 lineal feet of sewer per day are cleaned by a crew using this equipment. Cleaning through the use of this equipment is dependent upon the nearly complete blocking of the sewer cross-section by the ball or cone, the resultant build up of sewage head in the upstream sewer and manholes, and the resultant greatly increased pressure of the impounded sewage jetting around the periphery of the ball or cone and, in the case of the cone, from the 1½- or 2-in. opening at the advancing vertex of the cone. This relatively high-pressure jetting action effectively washes sand, silt, gravel, etc., downstream where, by use of a sand trap, it may be readily removed at the next downstream manhole. The ball or cone, of course, is controlled by use of a flexible wire rope and a hand-operated or power-driven winch located on the street surface at the upper manhole, and must be withdrawn in the event its further progress in the sewer is blocked for some unforeseen reason. It is particularly necessary to take great care in the use of these tools, that the sewage level in the sewer upstream is not built up to a point where flooding of connected basements or low fixtures will occur. Where such basements or low fixtures are likely to be affected it is good practice to station a crew member at the point of earliest overflow hazard to report any threatened flooding. It is important that immediate communication relations be established between this observer and the operating crew at the sewer manhole. The Section has used walkie-talkie portable radio units with great success for this purpose. When it is indicated to be necessary, the winch operator quickly manipulates the cleaning ball or cone to pass more sewage or quickly withdraws the tool to the manhole.

Where crews find grease or roots in not too excessive amounts the sewer is rodded with the hand tools and rods carried in the truck. Where grease and roots or other materials are present beyond the limits of reasonably easy removal with hand tools, a power sewer cleaning machine (of which the Division has three, and an additional one on order), and crew is used.

In the cleaning of sewers in excess of 24-in. diameter, power bucket sewer

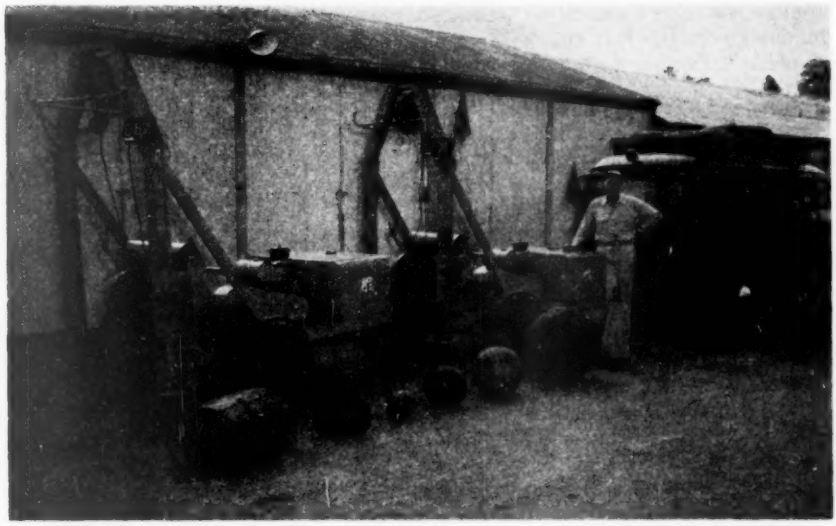

FIGURE 3.—Bucket-type sewer cleaning machines used by Pipeline Maintenance Section, with bucket, sewer cup, four sizes of sewer balls, sewer cone, and specially fitted truck.

cleaning machines, of which the Division has two, are used. Figure 3 shows some of the sewer cleaning tools carried by work crews.

Inspection Program

The planned inspection program is directed toward inspecting all sewers in the city at least twice a year. Additional inspections are provided for those points in the system where, because of unusual circumstances, more frequent inspection is deemed justified. The general program has proved quite satisfactory and emergencies have been kept at a reasonable minimum. A constant search is made for more effective, economical, and faster tools, equipment, and procedures. This is essential, as the Section is now operating on the basis of 30 mi. of sewer per pipeline maintenance employee, with a certainty that this unit mileage will increase under the tremendous sewer construction program now under way.

In view of the enormous investments in sewer systems in the many communities of the country, it is remarkable that so little support has been given to their operation. Although the public and city councils and Mayors more readily realize the necessity of furnishing money for the operation of sewage treatment and pumping plants, in general they are slow to understand the necessity for expenditures for the operation and maintenance of the sewers. Few, indeed, have the slightest conception of the vast network of sewers underlying the streets of a community, or of the difficulties encountered by sewer maintenance forces. It is one of the important duties of those in responsible charge of these systems to enlighten the proper officials as to the necessity of keeping the sewers clean, properly repaired, and ready at all times to serve their purpose.

If it be true that the general public in the respective communities is little aware of the sewers in the street, let us be sure that such lack of recognition is due to the fact that good sewer maintenance practices are keeping them

trouble-free and nuisance-free, and not due simply to the fact that the judgment day following neglect has not yet arrived.

Reference

1. Appel, A. A., "Explosive Gas Testing in Los Angeles." THIS JOURNAL, **25**, 12, 1460 (Dec., 1953).

DISCUSSION

By M. B. Nixon

Engineer in Charge of Sewers, Department of Construction, Atlanta, Ga.

Mr. Schneider has given an excellent description of a well-organized and efficiently operated sewer maintenance division in a large city and has highlighted some of its problems.

Although few if any cities have the problem of maintaining a 55-mi. outfall, the same conditions occur to a lesser degree in most sewer systems. As outfall sewers are extended farther and farther to serve new sections and as areas traversed by existing outfalls become more densely built up, the problem of odor control increases. It appears that in many cases consideration should be given to up-sewer chlorination or other remedies.

Of particular interest are the regular tests made for the purpose of detecting the presence of explosive gas in the sewer system. The seepage of gas from the gas mains, the seepage of gasoline from underground tanks, and the leakage otherwise of gasoline into the sewers is a constant threat of great potential damage.

Too much emphasis cannot be put on preventive maintenance. Good maintenance and repair can pay dividends in less interruption to service and longer life and usefulness of the sewers. Flushing and cleaning results in improvement of the quality and condition of the sewage reaching the treatment plant. This is apparently sometimes overlooked by those interested in sewage treatment. After all, the sewage reaching the plant is the raw material which the plant has to process. A sewage plant operator who has no concern for improving the quality and condition of the incoming sewage is like a manufacturer who has no concern for the quality of the raw material going into his product.

Due to the demands on the Sewer Division caused by recent annexation of 90 sq. mi. into the city limits of Atlanta, efforts at preventive maintenance have been handicapped.

In the older section of the city, covering an area of approximately 20 sq. mi., there is a combined sewer system. Many of the trunk sewers in this area are egg-shaped brick sewers. There has been considerable wear in the invert of these sewers and many have been repaired with granite blocks replacing the brick in the invert.

These trunk sewers discharge the dry-weather flow through grates or coarse bar screens into interceptor sewers, which carry the sewage to the treatment plants. The storm flow jumps the screens and is discharged into open channels or creeks. These screens are cleaned daily to prevent overflow of sewage into the creeks. As the interceptors are lower than the trunk sewers, they are usually on a flatter grade and considerable trouble has been caused by settling out of silt, gravel, cinders, etc., in the upper sections of the interceptors. Bucket machines are used to clean these interceptors and on some of them sand pits have been built which can be cleaned out with a clamshell operated by a motor crane.

As Mr. Schneider points out, preventive maintenance of sewers has received very little support from public officials. Probably some of this neg-

lect may be traced to lack of interest on the part of sewer operating and maintenance personnel. The subject has been neglected in most technical programs and short schools, usually being relegated to some minor spot if not left out altogether.

It is gratifying to see more interest being shown, as evidenced by the presentation of this paper and the fact that a Federation manual on sewer maintenance is now in preparation.

At the Georgia Water and Sewage Association Short School, held September 23–25, 1953, at Atlanta, a 2-hr. panel discussion was devoted to sewer maintenance and the effect of design and construction on maintenance. The five panelists, complete with moderator, sat on the platform, TV-style, discussing and answering questions on various problems. A great deal of interest was created and many practical questions were asked by those present.

Those responsible for planning the programs of Member Association meetings are urged to give more time and talent to this all-important subject.

INTERESTING EXTRACTS FROM OPERATION REPORTS

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage and Industrial Wastes Associations, Room 325, Illinois Bldg., Champaign, Ill.

Annual Report on the Operation and Maintenance of the Rochester, Mich., Sewage Treatment Plant for the Year Ended June 30, 1953 *

By Arthur Maass, *Superintendent*

Metered flow at the plant totaled 189.96 m.g. for the year, a drop of some 35.88 m.g. from the last year reported (1951). Of the total, Rochester contributed 183.49 m.g., or 96.6 per cent, and the Parke, Davis Biological Farm contributed 6.48 m.g., or 3.4 per cent. Much of the flow reduction is attributable to the reduced infiltration resulting from low ground-water levels caused by the extremely dry conditions of the report period and consolidation of the soil in areas of sewer extension projects during the past few years.

The plant continued to produce an effluent of good quality throughout the year. Settleable solids were reduced 88.9 per cent (from 5.11 to 0.57 ml. per liter), suspended solids were reduced 71.7 per cent (from 272 to 72 p.p.m.), and B.O.D. was reduced 52.1 per cent (from 255 to 119 p.p.m.)

A total of 12,140 lb. of chlorine was used during the year. This was equivalent to 7.8 p.p.m. applied. It maintained a residual of 0.64 p.p.m. in the effluent. The chlorinator was in service continually except for minor repairs.

No new areas of the plant grounds, were developed during the year, this type of activity consisting primarily of such refinements as finish grading, soil fortification with liquid sludge, seed-

* For last previous extract see This Journal, **25**, 4, 502 (Apr., 1953).

ing, etc. Some time was spent spraying the lawn with 2–4–D in attempts to kill the dandelions and other weeds.

No sludge was dried on the beds, all being used in liquid form as a soil fortifier on the plant grounds.

A summary of operating data for the year is presented in Table I.

TABLE I.—Summary of 1952–3 Operating Data, Rochester (Mich.) Sewage Treatment Plant

Item	Average
Population served	4,200
Sewage treated (m.g.d.):	
Total	0.520
Parke, Davis (biological farm)	0.018
Rochester	0.502
Grit removed (cu. ft./day)	3.8
Suspended solids (p.p.m.):	
Raw, Rochester	282
Raw, Parke, Davis	48
Effluent	72
Reduction (%)	71.7
B.O.D. (p.p.m.):	
Raw, Rochester	261
Raw, Parke, Davis	57
Primary effluent	139
Chlorinated effluent	119
Reduction (%)	52.1
Chlorine:	
Used (lb./day)	33
In effluent (p.p.m.)	7.8
Residual after 20 min. (p.p.m.)	0.64
Raw sludge:	
Pumped (g.p.d.)	1,123
Total solids (%)	5.3
Volatile solids (%)	70
pH	6.3
Total solids (lb./day)	488
Volatile solids (lb./day)	335
Digested sludge:	
Pumped to drying beds (gal.)	214
Total solids (%)	11.4
Total solids (lb./day)	101
Volatile solids (%)	45
Volatile solids (lb./day)	94
pH	7.8
Supernatant:	
Drawn from digester (g.p.d.)	941
Suspended solids (p.p.m.)	5,811
Gas production:	
Volatile solids consumed (lb./day)	220
Gas produced (cu.ft.) (estimated)	3,697
Operating expenses ($)	
Payroll	4,281.78
Power	289.88
Repairs and maintenance	256.46
Supplies	1,237.26
Miscellaneous	857.70
Total	6,923.08
Total cost per m.g.*	36.44
Total cost per capita*	1.65

* Includes Parke, Davis wastes.

Annual Operation Report of the Niles, Mich., Sewage Treatment Plant for the Year Ended July 31, 1953 *

By Charles V. Clem, *Superintendent*

Unusually dry weather resulted in low infiltration and decreased pumpage. This sharp reduction accounted for the abnormally high unit operation cost as compared with previous years, although the total operation and maintenance cost was only about $2,200 above that for 1952.

Operating activities were mostly routine, with the exception of adding 100 lb. of Enzymatic to the digesters. This addition increased the gas production to some extent but, more important, liquefied the solids so they could be pumped from the digesters. This gave more raw sludge storage room. If the preparation will aid in removing the digested sludge pumped out, it will save a lot of grief, as it will save the time and labor required to pump the digester down and clean it.

During the four-month chlorinating season, 13,421 lb. of chlorine were used to maintain a 0.53-p.p.m. residual in the effluent.

Table II is a summary of operating data for the report year.

* For last previous extract see This Journal, **25**, 8, 975 (Aug., 1953).

TABLE II.—Summary of Operating Data for Niles, Mich., Sewage Treatment Plant for the Fiscal Year Ended July 31, 1953

Item	Average	Item	Average
Rainfall, total (in.)	35.15	Dry solids (lb.)	2,200
Trib. population, est.	14,000	Vol. solids (%)	42
Sewage treated (m.g.d.)	1.8	Vol. solids, dry (lb.)	860
Grit, est. (cu. ft./m.g.)	0.39	Supernatant liquor:	
Total solids:		Amount (g.p.d.)	5,800
Raw sewage (p.p.m.)	935	Total solids (%)	0.32
Effluent (p.p.m.)	512	Vol. solids (%)	44
Reduction (%)	37	Digested sludge:	
Suspended solids:		To beds (gal.)	383,300
Raw sewage (p.p.m.)	270	Total solids (%)	11.4
Effluent (p.p.m.)	81	Total solids, dry (lb.)	162,950
Reduction (%)	62	Vol. solids (%)	56
Settleable solids:		Vol. solids, dry (lb.)	95,150
Raw sewage (ml./l.)	5.1	Gas production:	
Effluent (ml./l.)	0.32	Cu. ft. per day	8,782
Reduction (%)	80	Cu. ft. per lb. vol. solids	12.7
B.O.D.:		Cu. ft. per capita per day	0.45
Raw sewage (p.p.m.)	138	Chlorine:	
Effluent (p.p.m.)	75	Used (lb./day)	111
Reduction (%)	45	Residual in effl. (p.p.m.)	0.53
Raw sludge:		Oper. and maint. cost ($):	
Amount (g.p.d.)	4,220	Total	39,258.30
Total solids (%)	5.6	Per m.g.	61.63

GADGETS FOR SEWAGE TREATMENT PLANT OPERATION

By George T. Lohmeyer

Superintendent, Sewage Treatment Plant, University of Florida, Gainesville, Fla.

Gadgets, those plant-developed devices that give the sewage treatment plant operator the extra hands he seemingly always needs to ease his chores, are not the monopoly of a few individuals or even of a small group. Any plant operator, by a little search, can find literature references describing some kind of gadget to help him with almost any operational problem he may encounter. To give an idea as to how these literature references, either directly or by adaptation, can help in improving operation efficiency, is the object of this paper.

Sewage Sampling Devices

Various contrivances (Figure 1) have been made which aid in sampling sewage. Among the requirements to be considered on any sampler, commercial or otherwise, are the following:

1. The volume of the sample taken must be proportional to the flow.
2. The power source must be reliable.
3. The unit must be able to operate under adverse conditions of flow and weather.
4. The unit must be easily cleaned.

Martin (1), at Green Bay, Wis., assembled an automatic sewage sampling device in the following manner. A string of buckets was mounted on an endless chain powered by a gear-reducing electric motor. Samples caught at the bottom of the run were discharged into a trough at the top of the flight. With a constant-speed motor the volume collected could be changed by altering the number and size of

buckets. The sample size also could be altered by changing the motor speed through the simple expedient of placing a rheostat on the motor circuit. A further improvement would have been to adjust the rheostat automatically by attachment to a float in the sampled channel, thereby operating the sampler at speeds proportional to the flow.

The operators of the sewage treatment plant at Aurora, Ill., have improved their sampling technique by assembling a series of sampling cans, arranged in proportion to the flow rates. By using these proportional flow cans the operator does not have to calculate any certain sample volume to be taken for a given flow. He merely glances at a chart listing the can to be used for a given influent meter reading in order to make a proper 24-hr. composite.

Miscellaneous Gadgets

Operators with a considerable amount of skill in Morristown, N. J., have rigged up an electrically-controlled device on sludge valves that control the sludge level in the activated sludge secondary settling tanks. This is accomplished by means of a photoelectric cell wired to a sensitive relay.

The operation of sludge pumps in most all plants has brought about a number of refinements. For best operation a close study should be made of the volume and characteristics of raw sludge being pumped to the digester. Because of the increased volume and solids content of the supernatant liquor,

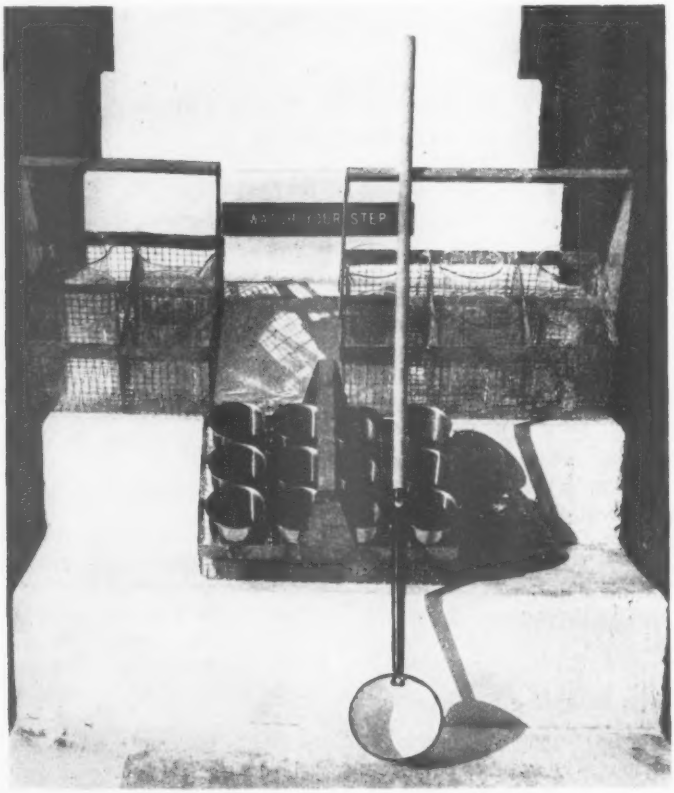

FIGURE 1.—Dipper, carrying cases, and beakers for collecting samples. Upper cases are used for sludge samples; lower case, for composite plant samples.

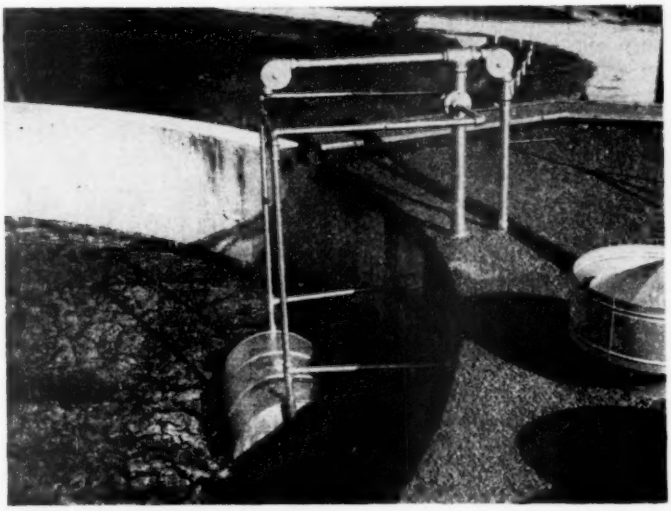

FIGURE 2.—Level indicator for open digester. A cable attached to the floating 55-gal. drum indicates the level of digester contents on a gage board inside the digester control building.

special attention should be given the raw sludge pumped. If neither pump discharge meters nor stroke counters are provided to measure the volume, the following methods might be of value. An electric clock (2) can be rigged up to the cold side of the motor switch through a transformer. In this way the clock will record the total time of pumping and can be totaled for each daily pumping period. The total volume pumped can be calculated by using the pump capacity rating. The accuracy of the method, of course, depends entirely on the accuracy of the pump capacity.

If a plant is operating with an open digester, another means of measuring the volume pumped is as follows. A 55-gal. drum, weighted with water for ballast, can be floated on the sludge surface. A change in elevation of the float, caused by a sludge pumping, is registered on a gage board inside the digester control building by the use of a set of pulleys. As shown in Figure 2, lateral movement of the drum is restricted by welding two vertical sleeves on the ends of the drum so as to slide on two pipes or rods rigidly fixed to the digester wall.

Frothing problems are causing an increased number of headaches for most operators regardless of the type of secondary treatment involved. Although chemical froth dispersers are available, one tested gadget which will eliminate part of the froth is a fine water spray directed over the location of most concentrated foam, as shown in Figure 3.

Chlorination equipment, even as set up in most modern plants, oftentimes requires refinements for reasons of operational safety. In plants which operate 24 hr. a day, chlorine might expire at any hour, which may be at a time when only one man is on duty. To overcome the risk of chlorine leaking while cylinders are being changed a foolproof procedure should be arranged. One method calls for a reserve supply of tested cylinders or cylinder standing by (Figure 4). In this way, the only duties necessary to tap a new chlorine source is the opening and closing of a series of valves.

Malfunctions of a sludge pump can be spotted by the use of two pressure-

vacuum gages, one mounted on each side of the piston. For a given pump under a given set of conditions, maximum vacuum and pressure gage readings can be determined by trial. During any pumping operation a deviation from these readings will indicate almost certain trouble. Such gages also give better indications of pump performance.

Digester Depth Sampling Gadgets

One phase of sewage plant operation receiving much attention from gadget-minded operators has been the problem of taking representative samples from the various levels of digesters.

One of the oldest of such devices, used today to some extent by Imhoff tank operators, is the hand-operated pitcher pump and a piece of weighted rubber hose. Other ingenious operators, not having a pitcher pump available, have constructed a sounding device of wire screen disks, 12 in. to 15 in. in diameter. The disk is suspended on a light-weight galvanized chain or wire graduated in 2-ft. intervals. The upper levels of the bottom sludge layer can be ascertained with ease by noting when the wire disk comes to rest on the sludge blanket.

One of the first homemade depth samplers consisted of a set of 32-oz. rubber stoppered bottles attached to a pole. Samples were taken by pulling a damper chain running to the top of the pole. Pulling this damper chain released all stoppers simultaneously, thus obtaining the required samples.

Sounding operations and depth samples have been taken from Imhoff tanks by using siphons. Generally a weighted rubber hose is lowered into the tank. Sufficient elevation of the tank is a necessity in using this method.

Scum blankets on open digesters have never ceased being operational problems. It is interesting to observe that any roundtable discussion by a group of operators on plant problems will invariably result in the question of scum formation on digesters. One method of attack consists of using a portable gasoline powered pump (Figure 5), which incidentally has numerous other uses about any plant.

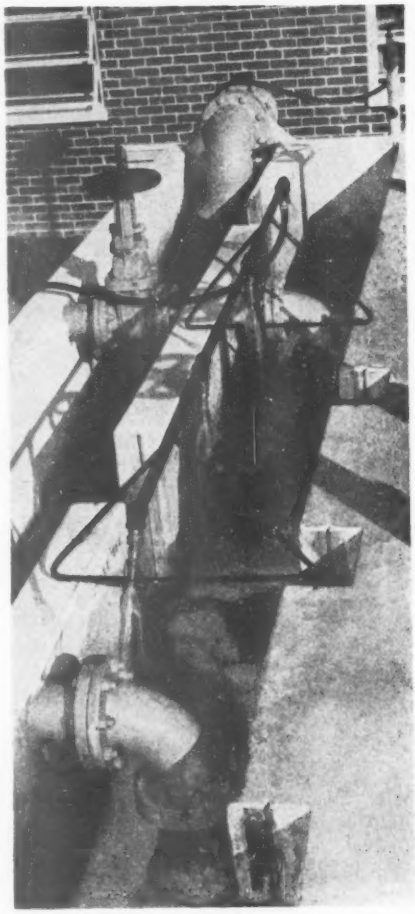

FIGURE 3.—Simple bracket holds water jets used for dispersing froth in open channel.

Laboratory Gadgets

"Legion" is the only word to be used in describing the array of gadgets assembled for use in the laboratory. All of the sundry items covered need not or should not be considered essential for every sewage treatment plant. However, the laboratory duties in every plant, regardless of the size,

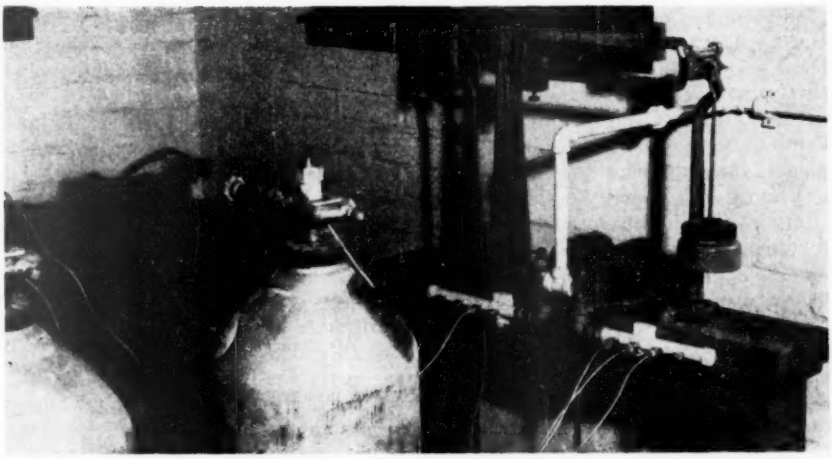

FIGURE 4.—Chlorine manifold, with alternate chlorine supply, previously tested, standing by.

have undoubtedly been eased by the use of homemade expedients.

Among the many simple gadgets in use in the laboratory are such staples as wash bottles, wooden drying racks for laboratory glassware, cork cutting tools, glassware flushing jets, and Gooch crucible holders consisting of a row of properly-sized corks attached to a block of wood, on which the crucibles can be stored.

Various ingenious gadgets have been produced for aiding in the process of setting up B.O.D. samples. If a number of dilutions are regularly made, special dilution cylinders can be assembled (3). The cylinder is constructed open at the top, with a stopcock at the bottom connected to a short piece of rubber tubing. In operation, a portion of the cylinder is first filled with dilution water, sewage is then added to achieve the proper dilution, and more dilution water is added to a

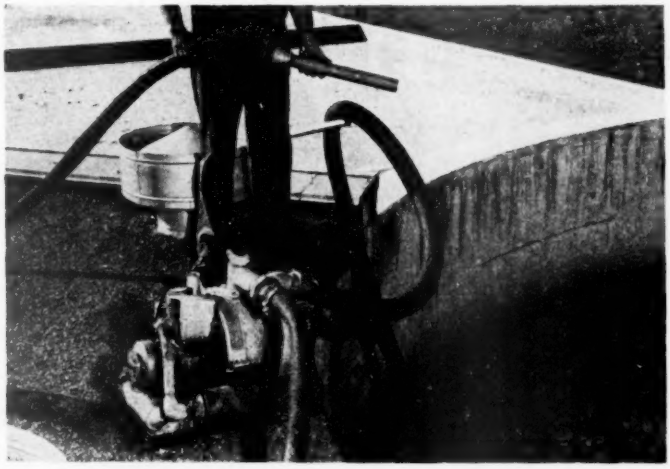

FIGURE 5.—Scum control rig for open unheated open digester. Digester liquor pumped from the supernatant level is discharged over the scum surface at weekly intervals.

predetermined point, generally the 1-l. mark. After sufficient mixing the diluted sample is added to a B.O.D. bottle through the rubber tubing attached to the bottom of the cylinder. A refinement to this gadget consists of replacing the stopcock at the bottom with a two-way cock, thereby permitting the addition of dilution water merely by turning a valve. A plastic augur mixing shaft powered by a small electric motor can be used for obtaining a properly mixed sample.

A simple laboratory gadget can be made for measuring a set volume of a liquid, such as the 200-ml. volume for the sample required for the standard D.O. titration. A volumetric flask is cut off at the desired volume etching. A rubber stopper is then placed over the mouth of the flask, which just fits into the 300-ml. ground-glass-stoppered bottle. If a minute hole is bored in the bottom of the flask much less time is required for draining the flask contents.

Addition of starch to a titration flask can be greatly hastened by rigging up a starch dispensing gadget. This device is composed of an inverted rubber-stoppered bottle with two holes bored through the stopper. One hole is used for an air pressure equalizer line and the other for the rubber tube starch feed line. A glass bead inserted in the starch feed line is squeezed to release a small supply of starch.

A great deal of variety is found in the laboratory gadgets. For instance, one operator rigged up a laboratory centrifuge by using a 4-blade electric fan (4). The device was supported by the heavy fan base. The fan shaft was set vertically. Two opposite blades were cut and bent so as to hold the centrifuge tubes.

A gadget reported from Jackson, Mich., provides a manifold for vacuum filtration (5). Rather than fitting just one suction flask to an aspirator, a manifold was assembled from ⅛-in. gas pipe and tees. The number of simultaneous filtrations was increased from one to four. A refinement on the above gadget for running suspended solids samples in larger volumes than 50 ml.,

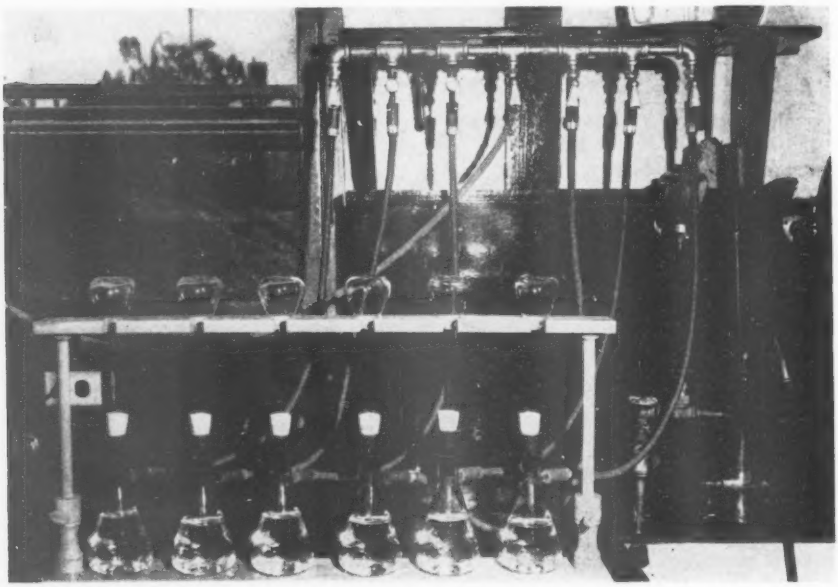

FIGURE 6.—Multiple vacuum filtering gadget for suspended solids. Sewage is automatically filtered through six Gooch crucibles from inverted volumetric flasks.

or where other duties prevent longer time being devoted to filtering samples, consists of setting up six suction flasks to a vacuum pump through a manifold as shown in Figure 6. Gooch crucibles set in Walter crucible holders in the suction flasks are constantly fed samples being filtered from volumetric flasks inverted over the crucibles and held by an adjustable funnel support stand.

Plant Record Gadgets

The subject of plant operation records and reports is closely related with the subject of gadgets used in operation. One of the "greatest enemies of plant neglect" is the conscientious filing of accurate reports to a supervisory agency. Few measures serve to keep plants more alert.

On the subject of records the extent to which a given plant will maintain records depends on the size and character of the particular plant, but no plant is so small that some form of simple record cannot be kept.

Among the gadgets found helpful for plants in this respect are card index systems for each motor and each piece of equipment for recording inspections, lubrication, and maintenance. A gadget for the filing of flow charts consists of a board with wooden dowels on which charts can be held (6). A triangular-shaped wire held in place by a spring clothes pin can be used to keep the stacks of charts in place. One thrifty operator has come up with the idea of re-marking flow charts on the back with a homemade compass device, thereby getting the use of two charts for the cost of one. If more than one set of flow charts are used in a plant, oftentimes small errors can be prevented by using a different colored ink in each recording pen.

Although it is not necessarily a gadget, an exceedingly helpful device for aiding in getting suggestions and ideas from plant staffs is the "operators log." Each operator is encouraged to jot down unusual operation experiences, suggestions, ideas, or constructive criticism of the plant management. Competition can be developed among the operators submitting the best gadget idea in such a "log."

For training new operators and for use as a reminder for regular employees one of the finest devices for assuring the performance of regular operation about a plant is to provide an operation check list for routine duties. It is necessary that such a check list be revised constantly to meet the inevitable changes and improvements which develop in a plant which is wide awake.

The few references and illustrations given represent only a small fraction of the help awaiting those who will only take the trouble to pursue their curiosity and natural bent for "improving" on things. Truly this is a case of "Seek and ye shall find."

References

1. Martin, G., "Automatic Sampler." *Sewage Works Jour.*, **9**, 1, 96 (Jan., 1937).
2. Bloodgood, D. E., "Automatic Timing Gadget for Sludge Pumps." *Sewage Works Jour.*, **11**, 1, 132 (Jan., 1939).
3. Backmeyer, D., "B.O.D. Dilution Dispenser." *Sewage Works Jour.*, **12**, 4, 805 (July, 1940).
4. Anderson, C. N., "Laboratory Centrifuge." *Sewage Works Jour.*, **9**, 1, 94 (Jan., 1937).
5. Greene, R. A., "Manifold for Vacuum Filtration." *Sewage Works Jour.*, **9**, 4, 657 (July, 1937).
6. Huffer, E. A., "Filing Rack for Record Charts." *Sewage Works Jour.*, **11**, 1, 134 (Jan., 1939).

TIPS AND QUIPS

The Humble Shall Be Exhausted

Writing under the above heading in the November issue of *Sewage Gas*, the Boise, Idaho, plant's quarterly, Operator C. S. Zickefoose comments on the attitudes exhibited by his non-initiated friends upon learning of his new occupation. Operators the world over will notice a similarity of pattern to their own experiences in the following excerpts from his remarks:

"Probably everyone engaged in this worthy work has been subjected to similar uncomplimentary remarks at one time or another. Some ask, upon learning my vocation, what I plan to do when I get a steady job. Others act as if I'd just come from a leper colony and seem afraid that something is going to rub off on them.

"'Isn't it awfully smelly?' is a common query of the uninformed and is akin to other questions asked out of pure ignorance as to the functions and condition of the plant.

"Although some of the fundamental processes of sewage treatment have been known for years, it wasn't until comparatively recently that the modern systems were put into practice. These have the coordination of several factors involving both mechanical and chemical know-how. The two are inseparable in the process of sewage treatment. This fact often is overlooked by the public in judging the mentality of a person connected with this type of work.

"The advent of any new science is always viewed with suspicion and there is invariably the sceptic who remembers back to the day when they got along without such new-fangled contraptions. The science of wastes treatment is not immune to such criticism, especially after the way it was handled in the past.

"However there is a bright side to the picture. All of my sceptical acquaintances that I have persuaded to come out to the plant and see what goes on, have a more favorable outlook of my occupation.

"This, I believe, is one way in which we can combat displeasure as to the reason for such an establishment. It is human nature to condemn that which we know little about and don't understand."

Chemical "Handbook" Available

What is essentially a "handbook" of water, sewage, and industrial waste treatment chemicals is available in convenient loose-leaf form from B–I–F Industries, Inc., Harris Ave., Providence, R. I. Issued as Technical Bulletin No. 10–K12, the 16-page booklet gives formulas, common names, uses, shipping data, characteristics, and feeding recommendations, including suitable handling materials, for 50 important chemicals used in these fields.

This should be a handy reference in any plant library.

Jet Age Plant Hazard

The personnel of the San Leandro, Calif., sewage treatment plant are awaiting the day that they may find themselves in the wholesale SOWHESS * membership business. The plant is adjacent to the Oakland airport and it has been feared on a number of occasions that a plane coming in for a landing would crash into a digester or splash into a sludge drying bed—or that an operator would "take to the tanks" to avoid a particularly low flyer!

* Society of Operators Who Have Experienced Saturation in Sewage.

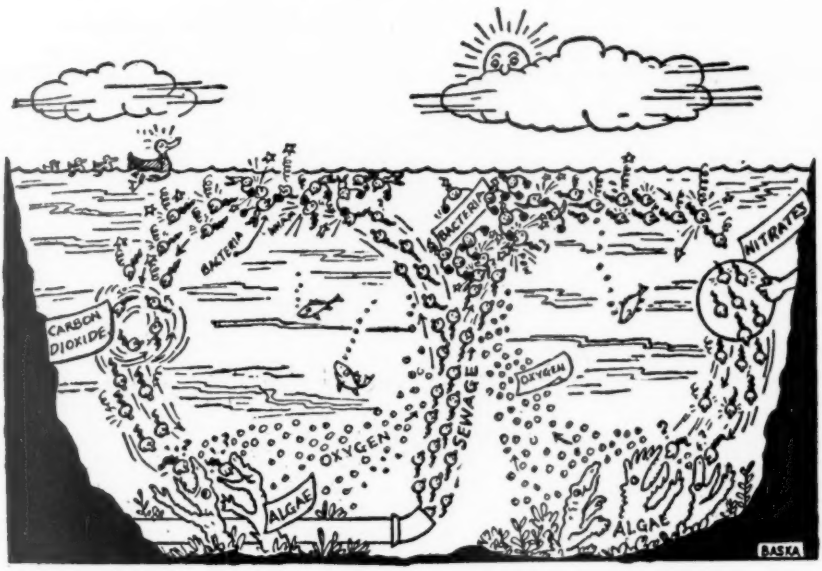

FIGURE 1.—Cartoonists'-eye view of action in a sewage lagoon.

Lagoon Process Depicted

In a whimsical presentation of what goes on in a sewage lagoon, artist W. M. Baska illustrates his impressions of the chemical and biologic action involved. His ringside-seat-view (Figure 1) shows the organic carbons and nitrogens of the sewage being broken up by aerobic bacteria into carbon dioxide and nitrates, on which goes back into the never-ending fight of the aerobic bacteria to reduce the organic material in the sewage and de-odorize it.

Lagoons are proving feasible for taking care of the sewage treatment needs of small communities in North Dakota.* Latest to be added to the growing list of towns in that state using the lagoon system of sewage treatment are Wishek and Larimore.†

The Wishek lagoon, serving a population of 1,240, is 7 acres in area and operates at about a 4-ft. depth of liquid. The inflow is the effluent from an old, badly overloaded Imhoff tank, located nearby. Cost of the lagoon was $3,750.49 for construction of the embankment, $227.29 for engineering services, and $318.37 for purchase and installation of iron pipe and valves. The installation was placed in service in October, 1952.

The Larimore installation utilizes automatic pumping to convey the sewage to the lagoon area, which is about three-fourths mile from the city limits. At present only one 10-acre lagoon is in operation to serve a population of about 1,400, two frozen-food locker plants, a creamery, a dairy plant, and a county hospital. Land has been purchased, however, for eventual expansion to 40 acres, so that additional capacity can be added at small expense as needed. The clay dikes are about 20 ft. wide at the top, 40 ft. wide at the bottom, and 6 ft. high. Topsoil was removed from the lagoon area to discourage vegetation growth. The operating level of the lagoon remains

* See THIS JOURNAL, **24**, 11, 1381 (Nov., 1952).

† *Official Bulletin, N. Dak. Water and Sewage Works Conf.*, **21**, 4, 16 (Oct., 1943).

fairly constant at 20-in. water depth. Total cost of this installation was about $38,000, including the purchase price of the land and filling of the area where the overflow of the old plant used to settle.

Two Michigan Explosions

Two explosions during 1953 at Michigan sewage works were briefly described by M. S. Richmond, Sanitary Engineer, Michigan Department of Health, in his "Review of Events in the Sewage Treatment Field," presented at the 1953 Annual Meeting of the Michigan Sewage and Industrial Wastes Association. The following are excerpts from Mr. Richmond's remarks:

"On April 29, 1953, a new sewage pumping station of the Beecher Metropolitan District at the northern edge of Flint, Mich., was destroyed by an explosion with an estimated loss in excess of $50,000. The explosion occurred in the pre-dawn hours of the morning when there was no attendant on duty at the plant. This was a new station, which was just being placed into service, and was equipped with what were thought to be adequate explosion safeguards. The wet well part of the station was separated from the dry well or pump room part, with a door in the wall between the two sections of the building in the superstructure. All electrical facilities in the wet well side of the station were of explosion-proof construction. The wet well was ventilated by a combination wind-motor driven ventilator. It is understood that the ventilator was being operated without benefit of power, due to the existence of a fairly strong wind, and the door between the two parts of the building had not yet been sealed. An analysis of the ventilation system, as installed, revealed that the actual capacity of the system had been reduced by excessive duct losses to about one-third of the capacity specified in the contract documents.

"In connection with the construction of the station, the influent sewer was passed beneath a gas main about one city block from the station. Apparently, the sewer trench was improperly backfilled and the fill settled, causing the gas main to rupture. Gas leaking from the broken main apparently found its way down into the pumping station. Evidently, the gas rose through the station and found its way into the motor room, where it was ignited, with the resultant disastrous explosion. This experience, among others, has re-focused the State Health Department's attention on ventilation of sewage plants and has impressed on all the necessity for adequate, positive, power-driven ventilation facilities and complete isolation of hazardous areas from sources of ignition.

"Another catastrophe occurred at the Cassopolis, Mich., sewage treatment plant, in which an operator was seriously injured. On March 9, 1953, the plant operator was engaged in painting in the basement of the service building. Following the painting project came a "clean-up" project, as usual, in which the floor was being cleaned with a flammable paint solvent. By accident, the glass solvent container was broken, spilling the solvent over the floor. In the ensuing explosion, Mr. Kugler suffered second and third degree burns, necessitating 14 weeks in a hospital and 4 additional weeks recuperating at home. It is of interest to note that there was no telephone at the Cassopolis plant with which to summon aid. It is of utmost importance that adequate means of communication be provided at sewage treatment plants, particularly at plants where only one person may be in attendance."

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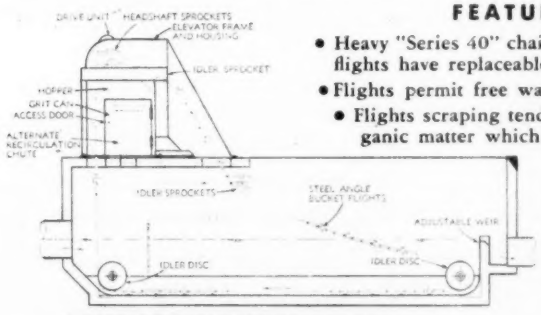

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Proceedings of Member Associations

WEST VIRGINIA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 7th Annual Meeting of the West Virginia Sewage and Industrial Wastes Association was held at Morgantown, W. Va., September 2–3, 1953. About 120 persons were registered for the meeting.

Among the technical papers presented were the following:

"Steel Industry's Attack on the Pollution Problem," by Henry A. Stobbs, Wheeling Steel Corp., Wheeling, W. Va.

"General Financing Methods," by Richard Hazen, Consulting Engineer, New York, N. Y.

"Financing Sewage Works in West Virginia," by Harold J. Shamberger, Research Assistant, Bureau for Government Research, West Virginia University, Morgantown, W. Va.

"Financing Experiences of the Sanitary Board of Charleston," by Donald Shonk, Manager, Sanitary Board, Charleston, W. Va.

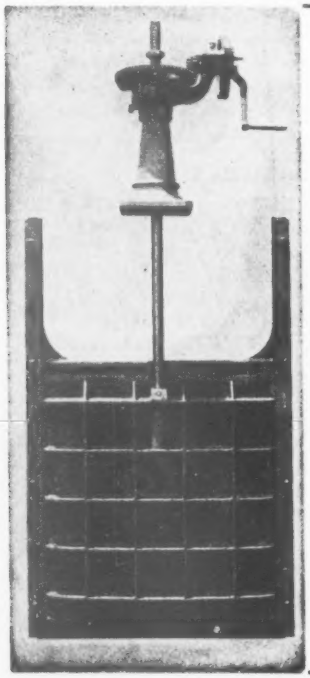
"Present West Virginia Legislation and Its Effects on Stream Pollution Control," a panel discussion.

Inspection trips were made to the Morgantown Experimental Station, U. S. Bureau of Mines, and the sanitary research facilities of the West Virginia University.

Officers were elected as follows:

President: W. D. Kelley, Charleston.
1st Vice-President: G. F. Jenkins, Charleston.

(*Continued on page 68a*)



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FSIWA Director: R. F. Rocheleau, Charleston.
Secretary-Treasurer: G. O. Fortney, Charleston.

GLEN O. FORTNEY,
Secretary-Treasurer

NORTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

The 25th Annual Convention of the North Dakota Water and Sewage Works Conference was held at the Clarence Parker Hotel, Minot, N. Dak., October 1–2, 1953. Registration totaled 129, including 18 ladies.

Among the papers presented were the following:

"Flow Characteristics of North Dakota Streams," by Harlan Erskine, U. S. Geological Survey.

"Lagoon Progress," by W. Van Heuvelen, State Health Dept., Bismarck, N. Dak.

There were also general group discussions on topics of interest in the water, sewage, and general public works fields.

The following officers were elected:

President: C. M. Hagen, Oakes.
Vice-President: P. Hays, Minot.
Secretary-Treasurer: J. H. Svore, Bismarck.

JEROME H. SVORE,
Secretary-Treasurer

KANSAS SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The Kansas Sewage and Industrial Wastes Association held its 1953 Annual Meeting in the Broadview Hotel, Wichita, Kans., on April 22–24, 1953, in conjunction with the Kansas Section, AWWA.

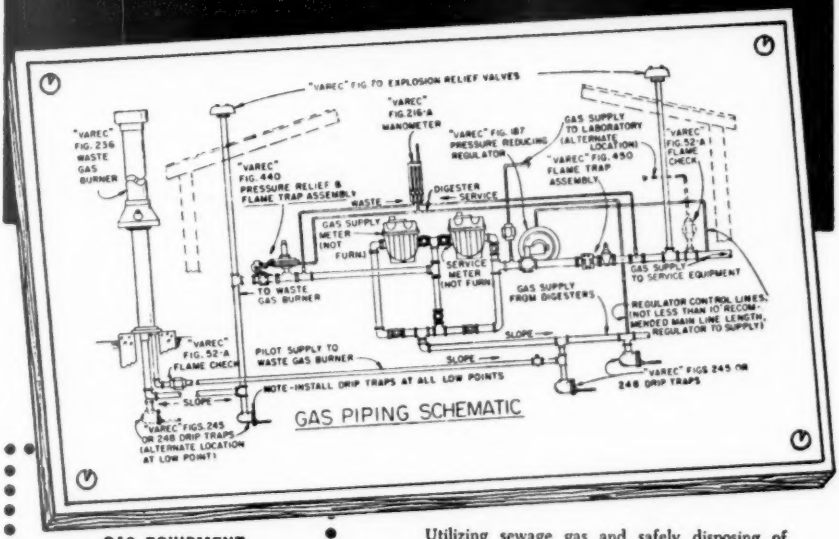
Officers were elected as follows:

President: W. Parr, Topeka.
Vice-President: L. Cunningham, Parsons.
Secretary-Treasurer: D. F. Metzler, Lawrence.

DWIGHT F. METZLER,
Secretary-Treasurer

(*Continued on page 70a*)

"VAREC" figures in *Your* SEWAGE TREATMENT PLANT DESIGN for SAFETY and GAS CONTROL


"VAREC" FIG. 70 EXPLOSION RELIEF VALVES
"VAREC" FIG. 236 WASTE GAS BURNER
"VAREC" FIG. 216-A MANOMETER
"VAREC" FIG. 187 PRESSURE REDUCING REGULATOR
GAS SUPPLY TO LABORATORY (ALTERNATE LOCATION)
"VAREC" FIG. 450 FLAME TRAP ASSEMBLY
"VAREC" FIG. 52-A FLAME CHECK
"VAREC" FIG. 440 PRESSURE RELIEF & FLAME TRAP ASSEMBLY
WASTE
DIGESTER SERVICE
GAS SUPPLY METER (NOT FURN.)
SERVICE METER (NOT FURN.)
GAS SUPPLY TO SERVICE EQUIPMENT
TO WASTE GAS BURNER
GAS SUPPLY FROM DIGESTERS
REGULATOR CONTROL LINES (NOT LESS THAN 10' RECOMMENDED MAIN LINE LENGTH, REGULATOR TO SUPPLY)
"VAREC" FIG. 52-A FLAME CHECK
PILOT SUPPLY TO WASTE GAS BURNER
SLOPE
SLOPE
"VAREC" FIGS 245 OR 248 DRIP TRAPS
NOTE-INSTALL DRIP TRAPS AT ALL LOW POINTS
SLOPE
"VAREC" FIGS. 245 OR 248 DRIP TRAPS (ALTERNATE LOCATION AT LOW POINT)

GAS PIPING SCHEMATIC

GAS EQUIPMENT SPECIFICATIONS

a. **PRESSURE RELIEF AND FLAME TRAP ASSEMBLY**
"VAREC" Fig. No. 440

b. **FLAME TRAP ASSEMBLY**
"VAREC" Fig. No. 450

c. **FLAME CHECK**
"VAREC" Fig. No. 52A

d. **EXPLOSION RELIEF VALVES**
"VAREC" Fig. No. 70-1

e. **WASTE GAS BURNER**
"VAREC" Fig. No. 236

f. **DRIP TRAPS**
"VAREC" Fig. No. 245 (automatic)
"VAREC" Fig. No. 248 (hand operated)

g. **MANOMETERS**
"VAREC" Fig. No. 216A

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The 1953 Annual Meeting of the Kentucky-Tennessee Industrial Wastes and Sewage Works Association was held in conjunction with that of the Kentucky-Tennessee Section, AWWA, at the Owensboro Hotel, Owensboro, Ky., on September 21–23, 1953. Registration for the meeting totaled 198, including 39 ladies.

Papers of sewage works interest included the following:

"Sanity in Sanitation," by E. Sherman Chase, President, FSIWA, Boston, Mass.

"Preliminary Findings on Pollution Conditions in the Ohio River from Cincinnati, Ohio, to Cairo, Illinois," by Robert K. Horton, Ohio River Valley Water Sanitation Commission, Cincinnati, Ohio.

"Safety in Utility Plants," by Robert W. Wilson, Manager, Commercial Business Promotion and Development, Kentucky Utilities Co., Lexington, Ky.

"Civil Defense and Its Relation to the Water and Sewage Works Industries," by Maj. Gen. J. S. Lindsay, Adj. Gen. of Kentucky.

"Expansion of the Owensboro Municipal Industries," by E. A. Farmer, Black and Veatch, Consulting Engineers, Kansas City, Mo.

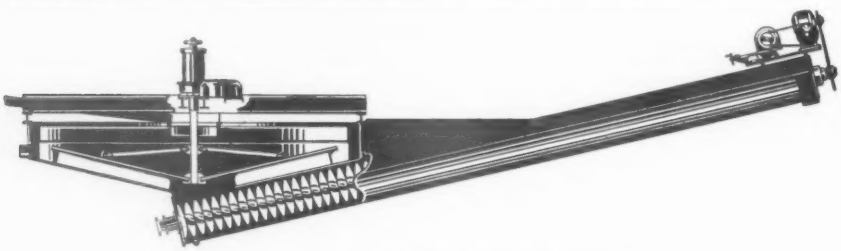
"Digesters for Sewage and Industrial Wastes," by A. M. Buswell, Chief, Illinois Water Survey, Urbana, Ill.

"Sewage Works Operators' Forum."

"What is New in the Sewage Treatment Field in Kentucky and Tennessee," by Louis F. Birkel, Kentucky Water Pollution Control Commission, and W. H. Owen, Tennessee Department of Public Health.

"Sanitary Engineering Experience in Brazil," by Julian R. Fleming, Professor of Sanitary Engineering, University of Tennessee.

(Continued on page 72a)



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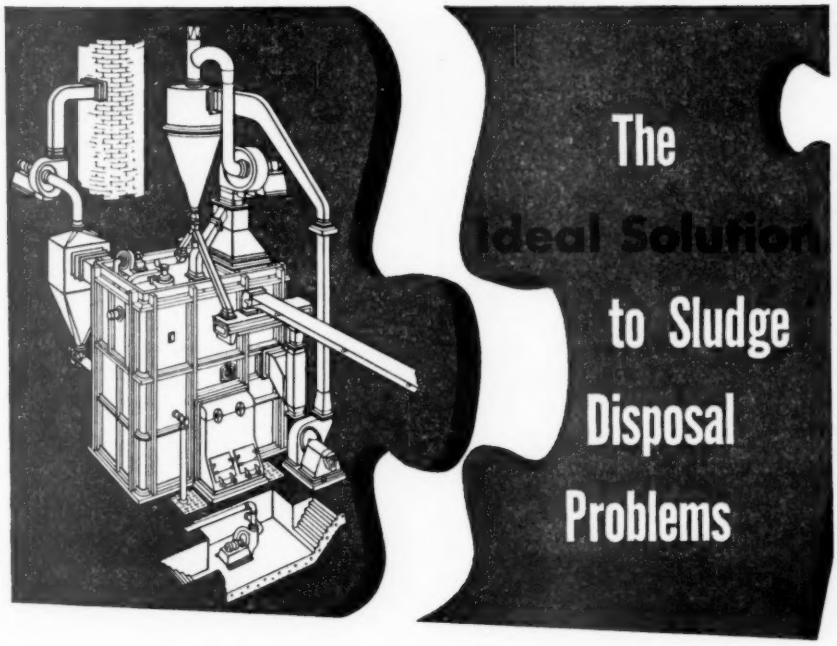

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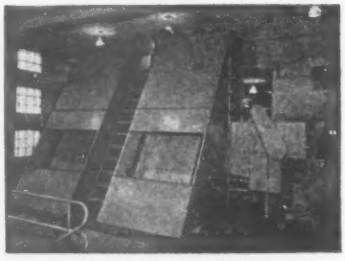

Gruendler Sewage Screening Shredder in connection with two Link-Belt Bar Screens, San Francisco, Calif.

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"The Design and Construction of Sewers to Prevent Excess Infiltration," by C. G. Gaither, Howard K. Bell, Consulting Engineers, Lexington, Ky.

"Analysis of a Stream's Capacity for Assimilating Pollution," by M. A. Churchill, Chief, Stream Sanitation Section, Tennessee Valley Authority, Chattanooga, Tenn.

"Cathodic Protection for Water and Sewage Works," by R. L. Spencer, Electro-Rustproofing Co., St. Louis, Mo.

"Engineering Reports and Rate Studies for Water and Sewer Systems," by J. S. Watkins, Consulting Engineer, Lexington, Ky.

"The Importance of the Engineering Report and Rate Studies from the Financier's Viewpoint," by P. M. Conway, Bankers Bond Co., Louisville, Ky.

The following officers were elected to serve during 1953–4:

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Vice-Chairman: R. P. Johnson, Lexington, Ky.
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SOUTH CAROLINA WATER AND SEWAGE WORKS ASSOCIATION

On October 8, 1953, the South Carolina Water and Sewage Works Association held its 1953 Annual Meeting at the Cities Supply Co. plant in Sumter, S. C. About 200 were in attendance.

Officers elected to serve during 1953–4 were as follows:

President: G. H. White, Columbia.
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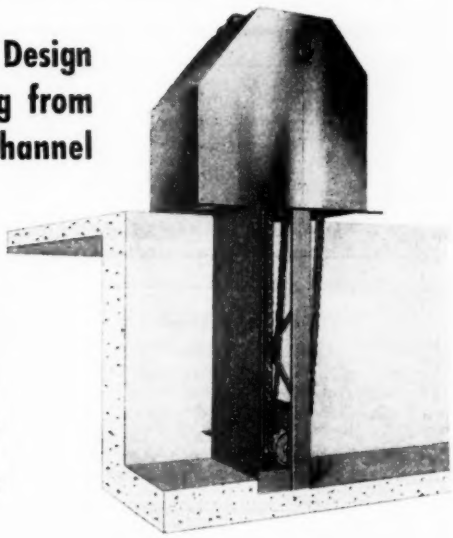
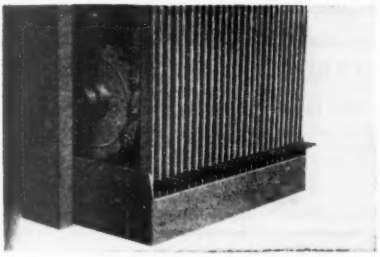
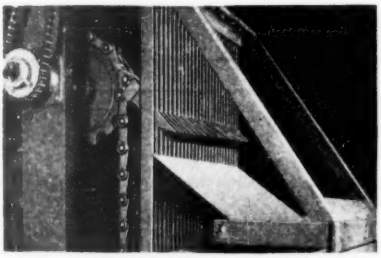




Horizontal position of rake teeth at the beginning of cleaning cycle accomplishes raking from absolute bottom of channel. Gets under and picks up all screenings—does not push them away • Note unobstructed channel approach.



Rake making 45° radial drop to discharge screenings into trough—Note shear pin hub with tool steel shaft and hub inserts for perfect shear action.

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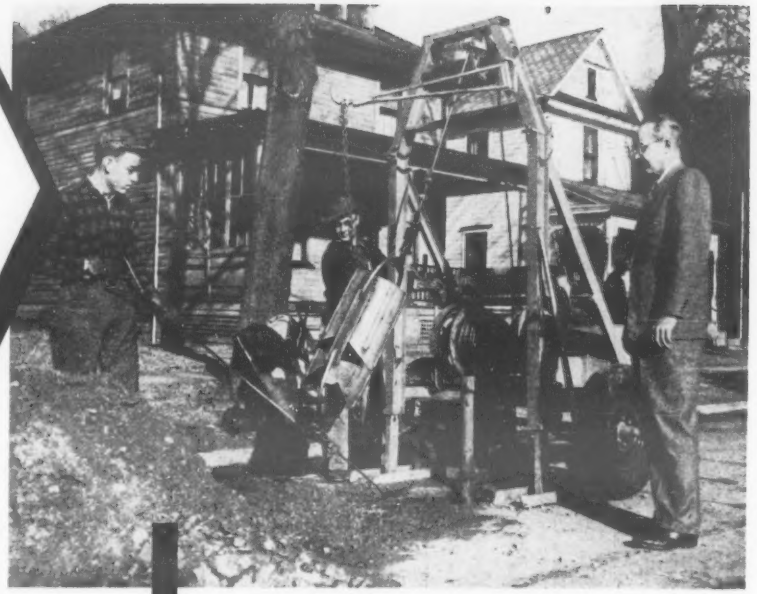

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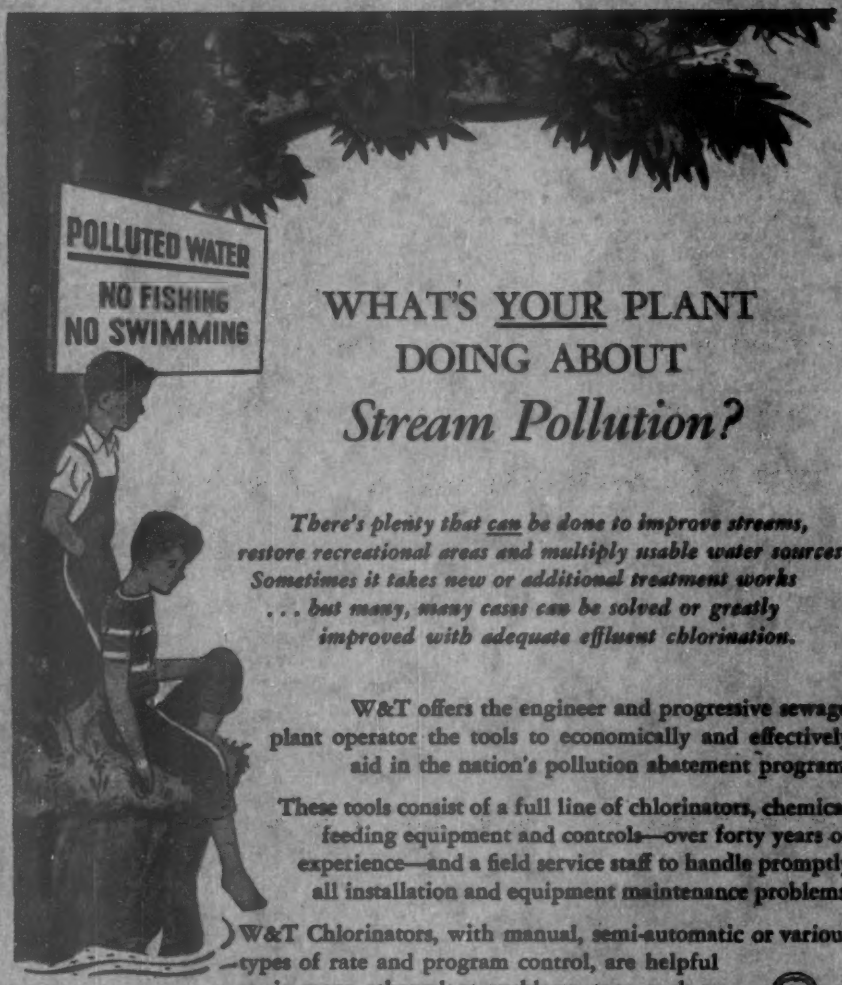

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